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Recovery Plan
for the
Mexican Spotted Owl
(*Strix occidentalis lucida*)

Plan de Recuperacion
del Tecolote Moteado Mexicano

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Recovery Plan for the Mexican Spotted Owl (*Strix occidentalis lucida*)

Plan de Recuperacion del Tecolote Moteado Mexicano *(Strix occidentalis lucida)*

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1995

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Date: Oct 16, 1995

DISCLAIMER:

This Recovery Plan is not intended to provide details on all aspects of Mexican spotted owl management. The Recovery Plan outlines steps necessary to bring about recovery of the species. The Recovery Plan is not a "decision document" as defined by the National Environmental Policy Act (NEPA). It does not allocate resources on public lands. The implementation of the recovery plan is the responsibility of Federal and State management agencies in areas where the species occurs. Implementation is done through incorporation of appropriate portions of the Recovery Plan in agency decision documents such as forest plans, park management plans, and State game management plans. Such documents are then subject to the NEPA process for public review and selection of alternatives.

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MEXICAN SPOTTED OWL RECOVERY PLAN

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EXECUTIVE SUMMARY

INTRODUCTION

The Mexican spotted owl was listed as a threatened species on 15 April 1993. Two primary reasons were cited for the listing: historical alteration of its habitat as the result of timber management practices, specifically the use of even-aged silviculture, plus the threat of these practices continuing, as provided in National Forest Plans. The danger of catastrophic wildfire was also cited as a potential threat for additional habitat loss. Concomitant with the listing of the Mexican spotted owl, a Recovery Team was appointed by FWS Southwestern Regional Director John Rogers to develop a Recovery Plan. This report constitutes the Recovery Plan for the Mexican spotted owl.

This Recovery Plan provides a basis for management actions to be undertaken by land-management agencies and Indian Tribes to remove recognized threats and recover the spotted owl. Primary actions will be taken by the USDA Forest Service, USDI Bureau of Land Management, USDI Fish and Wildlife Service, USDI Bureau of Indian Affairs, and sovereign American Indian Tribes. The Fish and Wildlife Service will oversee implementation of the Recovery Plan through its authorities under the Endangered Species Act.

The Team made every effort to identify and consider all sources of information in developing this plan. Previous plans developed for the northern spotted owl (Thomas et al. 1990, Bart et al. 1992) and the California spotted owl (Verner et al. 1992) were considered in the development of this Recovery Plan. The Team analyzed data that had not been evaluated previously and re-analyzed data when appropriate to ensure that information was consistent or to address questions not considered in previous analyses of those data.

RECOVERY GOAL

The purpose of this Recovery Plan is to outline the steps necessary to remove the Mexican spotted owl from the list of threatened species.

THE RECOVERY PLAN

The Recovery Plan contains five basic elements:

1. A recovery goal and a set of delisting criteria that, when met, will allow the Mexican spotted owl to be removed from the list of threatened species.

2. Provision of three general strategies for management that provide varying levels of habitat protection depending on the owl's needs and habitat use.

3. Recommendations for population and habitat monitoring.

4. A research program to address critical information needs to better understand the biology of the Mexican spotted owl and the effects of anthropogenic activities on the owl and its habitat.

5. Implementation procedures that specify oversight and coordination responsibilities.

Each of these elements is described briefly below.

Delisting Criteria

The primary threat to the Mexican spotted owl leading to its listing as a threatened species was the alteration of its habitat in Arizona and New Mexico as the result of timber management, specifically even-aged management. Mexican spotted owls use a variety of habitats, but are typically associated with multi-canopied stands of mature mixed-conifer and ponderosa pine-Gambel oak forests. Past logging using even-aged shelterwood prescriptions that included short rotations and the removal of large volumes of timber greatly simplified stand structures which adversely affected >300,000 ha (800,000 ac) of spotted owl habitat (Fletcher 1990). Existing Forest Plans call for continued use of shelterwood harvests, potentially leading to continued loss of owl habitat. However, the Team recognizes and is encouraged by recent efforts to amend existing Forest Plans to de-emphasize the use of even-aged silviculture and incorporate the management guidelines provided within this Recovery Plan.

The range of the Mexican spotted owl was divided into six Recovery Units in the United States and five in Mexico. Recovery Units were based on various factors including biotic provinces, the spotted owl's ecology, and management considerations. If delisting criteria are met, Recovery Units can be delisted separately. The following criteria must be met for delisting to be considered: (1) the population in the three most populated Recovery Units must be stable or increasing after 10 years of monitoring; (2) scientifically-valid habitat monitoring protocols are designed and implemented to assess (a) gross changes in habitat quantity across the range of the Mexican spotted owl, and (b) habitat modifications and habitat trajectories within treated stands; and (3) a long-term management plan is in place to ensure appropriate management for the spotted owl and its habitat. If these three criteria are met, then the Mexican spotted owl can be delisted within any Recovery Unit if threats have been moderated or regulated, and if habitat trends are stable or increasing.

Levels of Protection

General recommendations are proposed for three levels of management: protected areas, restricted areas, and other forest and woodland types (Table ES.1). *Protected areas* include a 243 ha (600 ac) "Protected Activity Center" (PAC) placed at known or historical nest and/or roost sites, slopes >40% in mixed-conifer and pine-oak forests that have not been harvested within the past 20 years, and administratively reserved lands. Harvest of trees >22.4 cm (9 inches) dbh (diameter at breast height) is not allowed within protected areas, but light underburning is permitted on a case-specific basis as needed to reduce fuels. Also, a fire risk-abatement program is proposed to allow the treatments of fuels using a combination of fuel removal and fire. This management can be conducted initially within 10% of the PACs, after which time the effectiveness of the program should be evaluated. Similar management can be conducted on steep slopes, but with no areal restrictions.

Restricted areas include ponderosa pine-Gambel oak and mixed-conifer forests and riparian environments. Target/threshold criteria are provided to define the proportion of the landscape that should be in or approaching conditions suitable for nesting and roosting. The remainder of the landscape should be managed in such a way to allocate stands to ensure a sustained provision of nest and roost habitat through time. Broad guidelines for riparian systems emphasize the maintenance and restoration of riparian areas to ensure a mix of size and age classes.

Other forest and woodland types include ponderosa pine and spruce-fir forests, pinyon-juniper woodlands, and aspen groves that are not included within PACs. No specific guidelines are proposed, but general recommendations are given to manage these areas for landscape diversity within natural ranges of variation.

Population and Habitat Monitoring

The Recovery Plan provides a detailed program to monitor spotted owl populations and habitats. Both are key components of the delisting criteria. Population monitoring is restricted to the three most populated Recovery Units because their spotted owl populations meet sample size criteria for the monitoring design. Further, these Recovery Units comprise the core Mexican spotted owl population and the Team assumes that their population status reflects that of the entire population. The design presented in the Recovery Plan entails the use of mark-recapture methodology on random quadrats to estimate key population parameters. The objectives of the habitat monitoring are (a) to track gross changes in habitat quality and quantity using remote sensing technology, and (b) to evaluate whether treatments meet the desired goal of setting stands on trajectories to become replacement habitat.

Table ES.1. Overview of management categories by vegetation type for lands not administratively reserved.

Vegetation Type	In Nest Area?[1]	Slope ≥ 40%	Timber Harvest Within Past 20 Years?	Management Category
Any	Yes			Protected
Mixed-conifer	No	Yes	No	Protected
Pine-Oak	No	Yes	No	Protected
Mixed-conifer	No	Yes	Yes	Restricted
Pine-Oak	No	Yes	Yes	Restricted
Mixed-conifer	No	No		Restricted
Pine-Oak	No	No		Restricted
Riparian	No	No		Restricted
Ponderosa Pine	No	No		Other types
Spruce-Fir	No	No		Other types
Pinyon-Juniper	No	No		Other types
Aspen	No	No		Other types
Oak	No	No		Other types

[1] Refers to land contained within a protected activity center.

Activity-specific Research Program

The Recovery Team made extensive use of scientific data. During the process of gathering and evaluating these data, it became evident that additional information was needed to refine the recovery measures. Past research efforts emphasized inductive approaches to gather information on basic life history needs of the spotted owl. Although these research efforts provided some key information, more rigorous and directed approaches will be needed to address questions on dispersal, genetics, habitat, populations, and effect of management on spotted owls and other ecosystem attributes.

Implementation Measures

Recovery Plans are not self-implementing under the Endangered Species Act. Thus, an implementation schedule is provided that outlines steps needed for the execution of the recovery measures. These implementation guidelines include the formation of an interagency working team for each Recovery Unit to oversee implementation of the recovery measures that encompass four broad areas: resource management programs, active management actions, monitoring, and research.

CONCLUSION

The Recovery Plan is based largely on final and preliminary results of field studies of spotted owl habitat use, population biology, and distribution. The Team relied on information published in the both scientific and "gray" literature. If data were available but unanalyzed, the Team made every reasonable effort to conduct those analyses. Reanalyses of data were conducted when the Team wished to address questions not addressed by those who collected the data. Thus, this Recovery Plan represents the current state-of-knowledge on the Mexican spotted owl.

The Recovery Plan recommendations are a combination of (1) protection of both occupied habitats and unoccupied areas approaching characteristics of nesting habitat, and (2) implementation of ecosystem management within unoccupied but potential habitat. The goal is to protect conditions and structures used by spotted owls where they exist and set other stands on a trajectory to grow into replacement nest habitat or to provide conditions for foraging and dispersal. By necessity this Plan is a hybrid approach because the status of the Mexican spotted owl as a threatened species requires some level of protection until the subspecies is delisted. These constraints modify ways and opportunities to manage ecosystems within landscapes where owls occur or might occur in the future. The Plan advocates applying ecosystem management in two slightly different ways. Within unoccupied mixed-conifer and pine-oak forest on <40 % slope, we provide both general (coarse filter) and specific (fine filter) guidelines to provide a sustainable quantity of replacement nest habitat across the landscape. Within other unoccupied forest and woodland types (e.g., ponderosa pine, spruce-fir, aspen, and pinyon-juniper), general guidance is provided for managing the landscape to meet multiple resource objectives including spotted owl foraging and dispersal habitat.

Management priority should focus on actions to alleviate threats to Mexican spotted owls; thereafter, or in coordination with alleviating threats, other management priorities (e.g., creating replacement owl habitat) should be pursued. Two primary threats that should be the focus of such management priorities are catastrophic wildfire and widespread use of even-aged silviculture.

Heavy accumulations of ground and ladder fuels have rendered many Southwestern forests vulnerable to stand-replacing fires. Such fires represent a real and immediate threat to the existence of spotted owl habitat. The management guidelines are intended to provide land managers with flexibility to reduce these fuel levels and abate fire risks. Fire management should be given the highest priority.

Even-aged silviculture within potential owl habitat is regarded as a threat because it tends to simplify stand structure and move stands away from containing owl habitat characteristics. The Team recognizes, however, that such regeneration cuts may provide useful tools in special circumstances to manage for spotted owls and other ecosystem objectives. Any use of even-aged management should be done sparingly and only after careful deliberation to ensure that it represents the best approach to meet management objectives.

Under proposed delisting criteria the owl could be delisted within 10 years, rendering the protection measures in this Recovery Plan obsolete. At that time, sufficient knowledge should be available to design a strategy for long-term conservation of the Mexican spotted owl. Many of the ecosystem management guidelines provided in this Plan will provide a foundation for development of the long-term strategy. In formulating the recommendations, the Team assumes that population and habitat status will be monitored in conjunction with implementation of these management guidelines. Therefore, the management guidelines are not meant to stand alone. Monitoring provides objective criteria to assess the efficacies of the management guidelines. Without both habitat and population monitoring, the status of the owl cannot be assessed and it should not be delisted. We further assume that existing management constraints on vegetative manipulations (such as size of openings and maintenance of hiding and thermal cover for other species) will remain in place. This assumption is especially critical for vegetation types—ponderosa pine, pinyon-juniper, aspen, and spruce-fir—for which we provide no specific management recommendations.

The Recovery Plan presents realistic goals for recovery of the species and its ultimate delisting. The goals are flexible in that they require local land managers to make site-specific decisions. Success of the plan, however, hinges on the commitment and coordination among the various Federal and State land management agencies, sovereign Indian nations, and the private sector to ensure that the plan is followed and executed as intended by the Team.

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Mexican Spotted Owl Recovery Plan

Volume I

1

Recovery Plan Development

Volume I, Part I

A. RECOVERY PLANNING

The USDI Fish and Wildlife Service (FWS) added the Mexican spotted owl to the List of Threatened and Endangered Wildlife (50 CFR 17.11) as a threatened species, effective on 15 April 1993. Section 4(f)(1) of the Endangered Species Act of 1973, as amended (Act) (16 U.S.C. 1531), requires the Secretary of the Interior (usually delegated to the Director of the FWS) to "...develop and implement (recovery) plans for the conservation of endangered species and threatened species...unless he finds that such a plan will not promote the conservation of the species."

To develop scientifically credible recovery plans for listed species, the FWS may appoint recovery teams comprised of scientists and resource specialists with expertise either on the species being considered or with other relevant expertise. In the case of the Mexican spotted owl, the FWS appointed the Mexican Spotted Owl Recovery Team (Recovery Team). A list of Recovery Team members and their areas of expertise can be found in Appendix A. A chronology of Recovery Team activities is provided in Appendices B and C.

Recovery teams present recovery plans to the FWS as their recommendation on the steps necessary to remove a species from the List of Threatened and Endangered Wildlife and Plants. Removal from the list, or "delisting," means the species is no longer in need of protection under the Act and is therefore considered "recovered." If deemed acceptable, the Director of the FWS Region assigned the lead for that species approves the plan.

The FWS, pursuant to requirements under section 4(f)(4) of the Act, published a Notice of Availability of the Draft Mexican Spotted Owl Recovery Plan in the *Federal Register* on March 27, 1995 (60 FR 15787). In addition to this general solicitation for information and public comment, the FWS sent copies of the draft Recovery Plan to numerous Federal and State agencies, Indian Tribes, county governments, environmental and industry groups, and others who had expressed interest in the Mexican spotted owl. Finally, specific professional organizations and individuals were asked to provide peer review of either the entire document or portions treating subjects within their specific areas of expertise. A list of reviewers is provided in Appendix E.

Recovery plans are neither self-implementing nor legally binding. Rather, approved recovery plans effectively constitute FWS policy on that listed species or group of species, thereby guiding the Service in conducting various processes required under the Act, such as section 7 consultation, conservation planning under section 10, and other procedures. In most cases, recovery plans are followed by other Federal agencies in compliance with the mandate under sections 2(c)(1) and 7(a)(1) of the Act to utilize their authorities in carrying out programs for the conservation of endangered and threatened species. In addition, State and local governments usually follow the recommendations of recovery plans in their species conservation efforts.

Section 4(f)(1)(B) of the Act specifies the contents of a recovery plan:

"(i) a description of such site-specific management actions as may be necessary to achieve the plan's goal for the conservation and survival of the species" (III.B);

"(ii) objective, measurable criteria which, when met, would result in a determination...that the species be removed from the list" (III.A);

"(iii) estimates of the time required and the cost to carry out those measures needed to achieve the plan's goal and to achieve intermediate steps toward that goal" (IV.C and IV.D).

B. LISTING

The Mexican spotted owl is one of three spotted owl subspecies (see II.A). Under section 3 of the Act, the term "species" includes "...any subspecies of fish or wildlife...". Although the Mexican spotted owl is a subspecies, it is sometimes referred to as a "species" in this document when discussed in the context of the Act or other laws and regulations. An "endangered species" is defined under the Act as "...any species which is in danger of becoming extinct throughout all or a significant portion of its range...." A threatened species is one "...which is likely to become an endangered species in the foreseeable future throughout all or a significant portion of its range." Section 4 (A)(1) of the Act lists five factors that can, either singly or collectively, result in listing as endangered or threatened:

"(A) the present or threatened destruction, modification, or curtailment of its habitat or range;

(B) overutilization for commercial, recreational, scientific, or educational purposes;

(C) disease or predation;

(D) the inadequacy of existing regulatory mechanisms;

(E) other natural or man-made factors affecting its continued existence."

The final rule listing the Mexican spotted owl as a threatened species (final rule) (58 FR 14248) provides a detailed discussion of the primary factors (A and D) leading to the determination of threatened status. It should be noted that the Recovery Team summarizes the final rule here for information purposes only. The Recovery Team's assessment of the current situation with regard to the subspecies' status and threats is reflected in Part III. The following briefly summarizes the factors leading to the species' listing, as discussed in the final rule:

THE PRESENT OR THREATENED DESTRUCTION, MODIFICATION, OR CURTAILMENT OF ITS HABITAT OR RANGE

Past, current, and future timber-harvest practices in the Southwestern Region (Region 3) of the USDA Forest Service (FS) were cited as the primary factors leading to listing the Mexican spotted owl as a threatened species. The final rule stated that the Southwestern Region of the FS managed timber primarily under a shelterwood harvest regime. This harvest method produces even-aged stands rather than the uneven-aged, multi-layered stands most often used by Mexican spotted owls for nesting and roosting. In addition, the shelterwood silvicultural system calls for even-aged conditions in perpetuity. Thus, stands already changed from "suitable" to "capable" would not be allowed to return to a "suitable" condition; and acreage slated for future harvest will be similarly rendered perpetually unsuitable for Mexican spotted owl nesting and roosting.

The final rule stated that "...significant portions of spotted owl habitat have been lost or modified," and cited Fletcher (1990) in estimating that 420,000 ha (1,037,000 ac) of habitat were converted from "suitable" to "capable." Of this, about 78.7%, or 330,000 ha (816,000 ac), was a result of human activities, whereas the remainder was converted naturally, primarily by wildfire. According to the final rule, forest plans in the FS Region 3 allowed for up to 95% of commercial forest (59% of suitable spotted owl habitat) to be managed under a shelterwood system. The loss of lower- and middle-level riparian habitat plus habitat lost to recreation developments were also cited in the final rule as factors in habitat loss.

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OVERUTILIZATION FOR COMMERCIAL, RECREATIONAL, SCIENTIFIC, OR EDUCATIONAL PURPOSES

The final rule stated that scientific research has the greatest potential for overutilization of the Mexican spotted owl, whereas birding, educational field trips, and agency "show me" trips are likely to increase as the owl becomes better known. The effects of these activities, either chronically or acutely, are unknown.

DISEASE OR PREDATION

The final rule stated that great horned owls and other raptors are predators of Mexican spotted owls. It also implied that forest management created ecotones favored by great horned owls, thus creating an increased likelihood of contact between the two species.

INADEQUACY OF EXISTING REGULATORY MECHANISMS

The final rule discussed various Federal and State laws and agency management policies, concluding that existing regulatory mechanisms were inadequate to protect the Mexican spotted owl. For further discussion on extant regulatory mechanisms, refer to Part IV.

OTHER NATURAL OR MANMADE FACTORS AFFECTING ITS CONTINUED EXISTENCE

The final rule cited wildfires as a past and future threat to spotted owl habitat. The potential for increasing malicious and accidental anthropogenic harm to the species was also cited as a possible threat. In addition, the final rule recognized the potential for the barred owl to expand its range into that of the Mexican spotted owl, resulting in possible competition and/or hybridization. It was speculated that habitat fragmentation may encourage and hasten this expansion.

C. PAST AND CURRENT MANAGEMENT OF THE MEXICAN SPOTTED OWL

Prior to the proposed listing of the Mexican spotted owl, some Federal agencies and involved States had conferred special status on the subspecies (e.g., State "threatened," FS "sensitive," FWS "candidate") in recognition of its rarity, habitat preferences and threats to those habitat types, and/or need of special management considerations. This section summarizes the special status assigned to the subspecies and the resulting conservation efforts.

FISH AND WILDLIFE SERVICE

The FWS listed the entire spotted owl species as a Category-2 candidate in its 6 January 1989 Notice of Review (54 FR 554). Category-2 candidates are those species that the FWS believes may qualify for listing as threatened or endangered but for which insufficient information is available to support the required rule-making process. The northern subspecies was listed as threatened in 1990; the California and Mexican subspecies remained in Category-2 candidate status.

The Mexican spotted owl was proposed for listing as a threatened species on 4 November 1991 (56 FR 56344) as a result of a status review prompted by a petition to list the subspecies. Following publication of the listing proposal, the FWS attempted to develop a conservation agreement with involved Federal agencies to conserve the Mexican spotted owl. This effort was unsuccessful, so the final rule was published on 16 March 1993 (58 CFR 14248). Critical habitat was not determinable at the time of listing.

Since the listing of the subspecies, the FWS has been conducting the processes associated with listed species under the Act, such as section 7 consultation on Federal actions that may affect the subspecies, issuance of research permits under Section 10, and recovery planning under section 4, including funding of several research projects.

Two petitions to delist the species have been reviewed by the FWS. In both cases, delisting was determined to be "not warranted" because the petitions failed to present substantial scientific and commercial information to support their assertion that the species should be delisted. Notices of those findings, including discussions of the issues raised in the petitions, were published in the *Federal Register* on 23 September 1993 (58 FR 49467) and 1 April 1994 (59 FR 15361).

The FWS proposed critical habitat for the Mexican spotted owl on 7 December 1994 (59 FR 63162), and published the final critical habitat rule on 6 June 1995 (60 FR 29914). Since that time, the FWS has been in consultation with action agencies on the effects of proposed and ongoing actions on critical habitat.

FOREST SERVICE

The primary administrator of lands supporting Mexican spotted owls in the United States is the FS. Most spotted owls have been found within FS Region 3 (including 11 National Forests in Arizona and New Mexico). The Rocky Mountain (Region 2, including two National Forests in Colorado) and Intermountain (Region 4, including three National Forests in Utah) Regions support fewer spotted owls.

Forest Service Southwestern Region (Region 3)

Prior to the listing of the Mexican spotted owl, FS Region 3 issued detailed guidelines for its management. Those guidelines were issued as Interim Directive Number 1 (ID No. 1) in June 1989, then revised and reissued as ID No. 2 approximately one year later. Although ID No. 2 expired in December 1991, FS Region 3 has continued managing under those guidelines.

Interim Directive Number 2 guidelines required establishing management territories around all nesting and roosting spotted owls, as well as territorial owls detected at night for which daytime locations were not recorded. All management territories except those on the Lincoln and Gila National Forests had a 182-ha

(450 ac) core area surrounded by 627 ha (1,550 ac) of the "best available" habitat, extending the area to 809 ha (2,000 ac) per management territory. On the Lincoln and Gila National Forests, the 182-ha (450 ac) cores were augmented by an additional 425 ha (1,050 ac) of habitat, for a total management territory size of 607 ha (1,500 ac).

Except for road construction, habitat degradation was not allowed within management territory cores. In the remainder of the management territory management activities, including timber harvest, were limited to 209-314 ha (516-775 ac). The FS guidelines provided no protection for unoccupied habitat except in wilderness areas and administratively restricted lands.

The FS Region 3 has been in the process of amending forest plans through the National Environmental Policy Act (NEPA) process to incorporate the management recommendations contained in this Recovery Plan. The Recovery Team commends that effort.

Forest Service Rocky Mountain Region (Region 2)

Region 2 of the FS formed a task force in 1992 to begin developing management guidelines for the Mexican spotted owl. These management guidelines are still in draft form and have not been formally approved and adopted by FS Region 2. However, management activities continue to be examined on a case-by-case basis, and ID No. 2 may be used as a general guideline.

Forest Service Intermountain Region (Region 4)

Prior to the listing of the Mexican spotted owl, biologists from FS Region 4 and Utah's other land and wildlife management agencies, plus owl researchers, formed the Utah Mexican Spotted Owl Working Group (Working Group). The Working Group meets annually to identify and address issues pertaining to the management and conservation of Mexican spotted owls in Utah (Kate Grandison, FS, Cedar City, UT, pers. comm.). The Utah Mexican Spotted Owl Technical Team (Technical Team) was formed by the Working Group to focus on spotted owl issues such as (1) potential impacts to Mexican spotted owls in southern Utah; (2) current research and future research needs and priorities; (3) inventory and monitoring protocols; (4) management suggestions suitable for application by all land management agencies in southern Utah; and (5) dissemination of information from the Working Group and Technical Team to management and administrative levels. The goals of the Technical Team, which is composed of biologists from the FWS, FS, USDI Bureau of Land Management (BLM), USDI National Park Service (NPS), Utah Division of Wildlife Resources (UDWR), and a researcher/technical consultant, are to provide land and wildlife managers with the information necessary to ensure the protection of Mexican spotted owls and to suggest strategies for managing spotted owl habitat in Utah.

The Technical Team developed "Suggestions for Management of the Mexican Spotted Owl in Utah." These suggestions were sent to line officers for approval on 5 August 1994. Management territories on the Manti-LaSal National Forest were established using these suggestions, although ID No. 2 has also been adopted by Region 4. Interim Directive No. 2 was modified in March 1994 in Region 4 to change the survey protocol to include only potential breeding habitat in canyon areas below 2,590 m (8,500 ft).

According to the suggestions, management territory size should be 1,330 ha (3,350 ac) with 355-ha (875 ac) core areas of canyon habitat. In addition, a 0.8-km (0.5 mi) protection area centered on the nest site was established to protect the nest stand and surrounding areas. Habitat degradation is not allowed in the management territory areas. A "potential dispersal area" extends 58 km (35.8 mi) beyond the perimeter of the management territory. This area can be used for timber harvest, but post-harvest conditions must meet a reasonable facsimile of the 50-11-40 dispersal rule developed by Thomas et al. (1990). Forest Service Region 4 continues to manage under ID No. 2, with the above modifications, except where superseded by the "Suggestions for Management of Mexican Spotted Owls in Utah."

OTHER FEDERAL AGENCIES

National Park Service

Several NPS-administered units are known to support Mexican spotted owls, including Zion, Capitol Reef, and Canyonlands National Parks plus Glen Canyon National Recreation Area in Utah; Mesa Verde National Monument in Colorado; Grand Canyon National Park plus Saguaro, Walnut Canyon, and Chiricahua National Monuments in Arizona; Bandelier National Monument in New Mexico; and Guadalupe Mountains National Park in Texas.

The National Park Service Organic Act protects all wildlife on National Parks and Monuments. However, no specific management guidelines are in place for Mexican spotted owls, and the effectiveness of applying general laws and policies for spotted owls is difficult to evaluate.

Bureau of Land Management

The BLM has developed management policies specifically for the Mexican spotted owl in Colorado and New Mexico. The Colorado guidelines state that "...in areas with a confirmed nest or roost site, surface management activities will be limited and will be determined on a case-by-case basis to allow as much flexibility as possible outside of the core area." The BLM in Colorado has management guidelines for oil and gas development where Mexican spotted owls are known to occur. No surface occupancy is allowed within 0.4 km (0.25 mi) of a nest or roost site, and restrictions on other associated activities apply between 1 February and 31 July. Spotted owl management policy by the BLM in New Mexico establishes and preserves cores of habitat wherever the owl is found. The BLM determines the size of the cores on a case-by-case basis.

The BLM in Colorado follows the survey techniques of the FS Region 3 spotted owl protocol. Management territories have not been designated for known birds. Surveys are conducted in areas of potential habitat where projects are planned that may be in conflict with spotted owl management.

The BLM in Utah has no specific internal guidelines on management practices for Mexican spotted owls. However, agency personnel did participate in producing "Suggestions for the Management of Mexican Spotted Owls in Utah." The BLM will incorporate management prescriptions for the Mexican spotted owl and its potential habitat into resource management plans as they are updated over the next several years.

The BLM in Arizona has no specific guidelines for managing Mexican spotted owls. However, the standard BLM procedure for assessing impacts on threatened or endangered species will be followed for projects proposed in spotted owl habitat. Guidelines for protecting the owl or its habitat would then be developed on a site-specific basis (Ted Corderey, BLM, Endangered Species Coordinator, Phoenix Office, pers. comm.).

Department of Defense

The Fort Huachuca Military Reservation (Post) in southeastern Arizona is the only military land known to support nesting Mexican spotted owls. On the Post, military activity in spotted owl habitat is generally confined to various foot maneuvers, although the Army is considering expanding some tank maneuvers into higher elevations where the owl occurs (Sheridan Stone, Fort Huachuca Military Reservation, pers. comm.). One spotted owl site has been popular with birders for a number of years, but the effect of this activity is unknown. The Army also considers wildfire to be a potential threat and assesses the possibility of wildfire ignition when designing military activities on the Post.

Wintering Mexican spotted owls have been found on Fort Carson, near Colorado Springs, Colorado, and breeding owls are present on the Fremont Military Operating Area, which includes FS and BLM lands designated for conducting military maneuvers. Finally, low-level military air operations in some areas have been identified as actions that may affect Mexican spotted owls. Such operations are likely to increase in the next several years, and the Department of Defense is currently funding studies of the effects of these activities on spotted owls (M. Hildegard Reiser, Holoman Air Force Base, pers. comm.).

STATES

Arizona

The Mexican spotted owl is listed as "threatened" on the list of "Threatened Native Wildlife in Arizona" (Arizona Game and Fish Department 1988). The Arizona Game and Fish Department has authority to manage wildlife under provisions of Arizona Revised Statute 17, the goal of which is to maintain State's natural biotic diversity by listing and protecting threatened and endangered species. "Threatened" species is defined as "...those species or subspecies whose continued presence in Arizona could be in jeopardy in the near future. Serious threats have been identified and populations are (a) lower than they were historically or (b) extremely local and small."

Threatened status provides no special protection to species, although it does provide a mechanism through which the state can allocate Heritage Program grants to fund research for specially designated species. However, general Arizona wildlife rules make it unlawful "...unless otherwise prescribed...for a person to...take, possess, transport, buy, sell or offer or expose for sale wildlife, except as expressly permitted ...."

New Mexico

The State of New Mexico confers no special status on spotted owls. However, New Mexico Statute 17-2-14 makes it unlawful "...for any person to take, possess, trap or ensnare, or in any manner to injure, maim or destroy birds of the order Strigiformes." However, permits may be obtained to take owls for purposes of Indian religion, scientific study, or falconry. In addition, persons who commercially raise poultry or game birds may legally kill any owl that has killed their stock.

Colorado

The Mexican spotted owl was listed as threatened by the Colorado Division of Wildlife (CDOW) in 1993. "Threatened" wildlife is defined as "...any species or subspecies of wildlife which, as determined by the Colorado Wildlife Commission, is not in immediate jeopardy of extinction but is vulnerable because it exists in such small numbers or is so extremely restricted throughout all or a significant portion of its range that it may become endangered." Threatened status protects wildlife species by making it unlawful "...for any person to take, possess, transport, export, process, sell or offer for sale...any species or subspecies of [threatened] wildlife...." In addition, the CDOW is legislatively mandated to "...establish such programs including acquisition of land...as are deemed necessary for management of...threatened species." An interagency working group coordinates spotted owl inventories throughout Colorado.

Utah

The UDWR included the Mexican spotted owl as a sensitive species on its 1987 Native Utah Wildlife Species of Special Concern list (UDWR 1987). "Sensitive" wildlife is defined as "...any wildlife species which, although still occurring in numbers adequate for survival, whose population has been greatly depleted, is declining in numbers, distribution, and/or habitat (S1); or occurs in limited areas and/or numbers due to a restricted or specialized habitat (S2)." A management program, including protection or enhancement, is needed for these sensitive species.

The owl's status was elevated to "Threatened" in the revised draft list in 1992 (UDWR 1992). According to UDWR definition, "threatened" species include "...any wildlife species, subspecies, or population which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range in Utah or the world."

Both sensitive and threatened species receive "protected" status under Utah's wildlife codes. For species under protected status, "...[A] person

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may not take...protected wildlife or their parts; an occupied nest of protected wildlife; or an egg of protected wildlife." Nor may a person "...transport,...sell or purchase...or possess protected wildlife or their parts."

Texas

Few Mexican spotted owls are documented for Texas, and most of the location records are in Guadalupe National Park. Thus, the State of Texas has no spotted owl program. However, Texas Parks and Wildlife Code Section 64.002 provides protection for nongame birds by prohibiting killing, trapping, transportation, possession of parts, and the like. Destruction of eggs and nests of nongame birds is also prohibited.

TRIBES

Tribal beliefs and philosophies guide resource management on Tribal lands. Several Tribes consider owls a bad omen; however, Tribal beliefs also dictate that all living creatures are essential parts of nature and, as such, they are revered and protected. For example, the Elders Council of San Carlos Apache Tribe expressed the traditional view that owls and their homes should not be disturbed.

Mexican spotted owl habitat or potential habitat exists on 10 Indian reservations in the Southwest. Eight of the Tribes have conducted spotted owl surveys, and five Tribes have located spotted owls on their lands. Two other Tribes have historical spotted owl records.

Reservations were established for the benefit of the Tribes and their members. Tribal lands are held in "trust" by the Federal Government. They are not considered public lands or part of the public domain. Tribes are sovereign governments with management authority over wildlife and other Tribal land resources. Many Tribes maintain professionally staffed wildlife and natural resources management programs to ensure prudent management and protection of tribal resources, including threatened and endangered species.

The FWS is aware of spotted owl conservation efforts on five Indian reservations: the Mescalero Apache, Fort Apache, San Carlos Apache, Jicarilla Apache, and Navajo Nation.

Mescalero Apache Tribe

The Mescalero Apache Tribe in New Mexico actively manages their forest while managing for all federally listed or proposed threatened or endangered species that may exist on the reservation, including the Mexican spotted owl. This is accomplished through developing strategies for identifying and managing habitat determined by the Tribe to be necessary to ensure protection. The Mescalero has been working with the FWS in development of a conservation strategy for the subspecies on reservation lands.

White Mountain Apache Tribe

The Tribe recently developed a conservation plan for Mexican spotted owls on the reservation. Areas containing spotted owls are placed in one of two land-management categories, termed Designated Management Areas (DMAs). Areas supporting "clusters" of four or more territories are considered "Category-1" DMAs. In these areas, spotted owl habitat concerns drive management prescriptions; timber harvest is a secondary objective. Category-1 DMAs range from about 2,430-4,050 ha (6,000-10,000 ac), and contain 57% of known spotted owl sites on the reservation.

"Category-2" DMAs include areas supporting 1-3 owl territories. Habitat outside the territories is managed only secondarily for spotted owls, with other resource objectives given priority. No timber harvest is allowed in 30-ha (75 ac) patches around owl activity centers. A seasonal restriction on potentially disturbing activities is provided in a 202-ha (500 ac) area, and timber prescriptions within this area should be designed to improve habitat integrity.

The Tribe continues to survey their lands for spotted owls. If more owl sites are detected, Category-1 and Category-2 DMAs may be established upon approval by the Tribal Council.

San Carlos Apache Tribe

Spotted owl surveys on the San Carlos Apache Reservation have been conducted according to the FS Region 3 Mexican Spotted Owl Inventory Protocol. Mexican spotted owl habitat has been identified and delineated throughout the reservation. A joint Tribal/Bureau of Indian Affairs interdisciplinary team evaluates effects of actions on spotted owls. Any potential impact on spotted owls or owl habitat is deferred until compliance with the Act and associated regulations is attained.

Preliminary discussions between the San Carlos Apache and the FWS have taken place regarding development of specific spotted owl management guidelines. Approximately 90% of tribally identified nesting, roosting, and foraging habitats are on lands inoperable for timber harvest and therefore are not in the commercial timber base.

Jicarilla Apache Tribe

The Jicarilla Apache Tribe has developed a spotted owl conservation plan, approved by the Jicarilla Tribal Council and accepted by the FWS. No resident owls have been detected to date on the reservation; however, in the event resident owls are detected, the Tribe has proposed to designate a 405-ha (1,000 ac) management territory. Uneven-aged timber management will be allowed to continue in all but 40 ha (100 ac) of the territory. In the absence of confirmed resident owls, all mixed-conifer stands of 10 ha (25 ac) or greater are treated as roosting/nesting sites, and timber harvest will not be allowed. A seasonal restriction around any active nest sites that are found is also proposed.

Navajo Nation

Mexican spotted owl management on the Navajo Nation, and particularly on the Navajo Nation Commercial Forest, currently adheres to FS Region 3's ID No. 2. The FS Region 3 Mexican Spotted Owl Inventory Protocol is followed for all timber sales on the commercial forest and for any project or disturbance, on or off the commercial forest, that may impact spotted owls. The current Navajo spotted owl inventory program is limited to areas where timber sales or other projects are planned.

The Navajo Nation is developing a multi-species conservation plan, including management guidelines for spotted owl conservation, in conjunction with their 10-year plan for managing commercial forest. Upon completion of the multi-species conservation plan, the Navajo Nation may apply to the FWS for a section 10(a)(1)(B) permit, which will allow limited incidental take to occur provided an adequate habitat conservation plan is implemented.

MEXICO

The Mexican spotted owl is listed as a threatened species under Mexico's Official Mexican Norm (NOM) (NOM-059-ECOL-1994). Threatened species are defined as those which could face danger of extinction if the conditions that cause deterioration or modification of their habitats, or decline of their populations, prevail.

Species listed under NOM are afforded certain protections:

1. Possession, use, or derivation of profit from live wildlife or plants, whether originating in captivity or in the wild, are prohibited.

2. Use and exploitation of the habitats of listed species are prohibited in some States.

Some use of threatened species is allowed for scientific and recovery purposes. For example, specimens and their parts, products, and by-products can be removed from their natural environment for scientific purposes under permits issued by legal authorities, with the understanding that specimens or their parts cannot be used for commercial purposes. In addition, specimens can be removed from the wild for the purpose of captive breeding upon approval of the Mexican government.

Under NOM, recovery plans have been prepared for sea turtles and the monarch butterfly. The Government and other institutions have shown interest in the conservation of other species such as manatees, yellow-headed parrots, and Mexican spotted owls, but currently no recovery plans are in place for these species.

Social, economic, and political systems differ in Mexico from those in the U.S. Concomitantly, land ownership patterns differ and influence natural resource management. Mexican lands are classified into three types of tenancy:

1. Federal lands include all lands administered under Federal Government institutions. Federal lands include protected natural areas such as Reserves of the Biosphere, National Parks, and Areas of Protection of Natural Resources. Protected natural areas comprise 3% of the total area of Mexico's five recovery units.

2. Ejidal lands are allotted by the Mexican Government to a person or community for agriculture, forestry, mining, and other uses. Thus, lands within ejidos are intensively managed for natural resource use. Ejidos comprise approximately 17.5% of the area within the Mexican recovery units.

3. Private lands are possessed under a "certificate of inaffectability." Any protection afforded these lands is at the discretion of the landowner. Approximately 79.5% of the Mexican recovery units is comprised of private land.

D. CONSIDERATIONS IN RECOVERY PLAN DEVELOPMENT

This section describes various considerations, other than the basic biology of the Mexican spotted owl, that were integral in development of this Recovery Plan.

RECOVERY UNITS

The Mexican spotted owl is a widespread subspecies that occurs in a wide variety of habitats (see Part II). In addition, the threats faced by the subspecies, the management regimes employed by various agencies and in each country, and the protective mechanisms available in different portions of the subspecies' range are variable. Finally, spotted owl densities, food habits, degree of isolation, and other aspects of the subspecies' biology differ somewhat among portions of its range. For these reasons, the Recovery Team partitioned the Mexican spotted owl range into distinct recovery units. Six recovery units were designated in the United States: Colorado Plateau, Southern Rocky Mountains - Colorado, Southern Rocky Mountains - New Mexico, Upper Gila Mountains, Basin and Range - West, and Basin and Range - East (Figs. II.B.1 and II.B.3–II.B.8). Five recovery units were established in Mexico: Sierra Madre Occidental - Norte, Sierra Madre Occidental - Sur, Sierra Madre Oriental - Norte, Sierra Madre Oriental - Sur, and Eje Neovolcanico (Figs. II.B.2). For a complete description of the recovery units and the bases for their designation see II.B.

Whereas some management recommendations apply to the subspecies rangewide, delineating recovery units allowed specific recommendations to be prioritized appropriately within each portion of the subspecies' range. In addition, some criteria for delisting the subspecies apply at the recovery-unit level. This approach allows delisting of the Mexican spotted owl by recovery unit when certain rangewide population and habitat criteria are met and when regional management plans or other sufficient regulatory mechanisms are implemented.

THE CURRENT SITUATION

In developing this Recovery Plan, the Recovery Team considered various aspects of the current spotted owl population, habitat, and threats. Two salient points emerged. First, the Recovery Team assumes that the current population size and distribution are adequate for providing a reference point for assessing future changes in the population, since no undisputable evidence is available indicating that the population is declining or is significantly below historical levels. This is a critical assumption that must be tested through the population monitoring required by this Recovery Plan. If the monitoring data demonstrate that the population is stable or increasing, the assumption of adequate population size will be validated. Conversely, if monitoring data show a decreasing population, the situation will need to be reexamined and corrective measures must be developed. Thus, the population and habitat monitoring requirements are essential parts of this Recovery Plan; if these monitoring efforts are not conducted, the management recommendations provided herein cannot stand alone.

A second consideration involves variations in both spotted owl densities and threats faced throughout the subspecies' range. Spotted owl densities are greatest in the center of the subspecies' range and they decrease toward the range periphery. In addition, the main threats identified during the listing process were forestry practices and wildfire risk, both of which vary across the subspecies' range. Table I.D.1. illustrates the Recovery Team's appraisal.

The Upper Gila Mountains, Basin and Range - West, and Basin and Range - East Recovery Units have significant owl populations with the potential of being seriously impacted by fire and/or forestry practices (Table I.D.1). This conclusion does not imply that the other recovery units are not important, but leads to the recommendations that (1) recovery efforts concentrate on recovery units with the highest owl populations and where significant threats

Table I.D.1. Summary of relative Mexican spotted owl population size, timber harvest threat, and fire threat by U.S. Recovery Unit.

		Threat Significance	
Recovery Unit	**Population**	**Fire**	**Timber**
Colorado Plateau	low	moderate	low
Southern Rocky Mtns-CO	low	high	low
Southern Rocky Mtns-NM	low	high	high
Upper Gila Mountains	high	high	high
Basin and Range - West	high	high	low
Basin and Range - East	high	high	high

exist; (2) management within recovery units should emphasize alleviating the greatest threats; and (3) the management recommendations in Part III should be tailored to the owl population and the threats existing in the specific area under analysis.

The Recovery Team believes the risk of extirpation of Mexican spotted owls under the near-term management recommendations is low. This belief is based on two points:

1. Implementation of the management recommendations within this Recovery Plan (see Part III) will protect occupied habitat, protect other habitat that can presumably be occupied in the near future, and allow for "replacement" habitat to develop and be sustained on the landscape. Habitat monitoring as required by this Recovery Plan should provide data on habitat trends throughout Recovery Plan duration.

2. The population will be monitored over the life of the Recovery Plan, thus providing insight as to whether the current "baseline" population is sufficient to maintain the subspecies over time and testing the assumption that the "baseline" population is adequate. The Recovery Team did not make the assumption that the "baseline" population is adequate lightly, but reasoned that the Mexican spotted owl is well distributed throughout its historical range, suggesting that no significant extirpations have occurred.

RECOVERY PLAN DURATION

Any management plan must specify the time period over which the plan is to be implemented. The Recovery Team decided that a 10-year period is appropriate for the Mexican Spotted Owl Recovery Plan (assuming the delisting criteria specified in III.A are met) for several reasons:

1. Ten years allows adequate time to monitor the trends in population and habitat. The charge of the Recovery Team was to develop a plan that would lead to recovery of the subspecies. In developing the delisting criteria specified in III.A, the Recovery Team reasoned that the population must be stable or increasing before the subspecies could be considered for delisting. The Recovery Team further determined that a monitoring period of 10 years would provide information about population trends that could be used with a reasonably high level of confidence. The five-year monitoring period the Act requires after a species is delisted will further increase confidence in trend information.

2. A 10-year period should be sufficient time to fill some of the major gaps in existing knowledge, and accommodate possible changes in future conditions. Many aspects of Mexican spotted owl biology remain unknown or poorly understood. Consequently, the effects of

different resource-management practices on the fitness of individuals and on population persistence remain unclear. A better understanding of these relationships is needed before a viable long-term management plan can be developed. Implementing the Recovery Plan includes conducting the research activities recommended in III.D; if these studies are started immediately, 10 years should be adequate to complete the majority of them.

3. Uncertainty about the future could render this Recovery Plan inadequate, unacceptable, or otherwise obsolete. Future events and developments could have social, economic, environmental, and other ramifications that cannot be predicted. To try to plan beyond the next decade or so would require an unjustified confidence in our ability to predict the state of our society and the environment.

4. Consistency with the requirements of the Act. The Act requires that the status of listed species be reviewed every five years. This Recovery Plan constitutes an in–depth status review of the Mexican spotted owl, so a formal status review should be conducted in years five and 10 of Recovery Plan implementation. Unless new information or other developments render this Recovery Plan obsolete in the interim, the 10-year point should mark the end of this Recovery Plan and implementation of a longer-term management strategy.

Several reviewers of the draft version of this Recovery Plan pointed out that this relatively short Recovery Plan duration fails to take into account the long-term processes that have influenced and will continue to influence dynamic ecosystems. The Recovery Team believes, however, that the management recommended for the next few years was developed with consideration of the long- and short-term effects of these near-term management recommendations.

Based on the foregoing points, the Recovery Team recommends a Recovery Plan duration of 10 years unless data indicate that earlier revision is appropriate, or that the applicable recommendations be continued beyond that time. The monitoring and research to be conducted during the life of the Recovery Plan will resolve much uncertainty surrounding the Mexican spotted owl. The uncertainty about the future can never be resolved, but a better understanding of Mexican spotted owl natural history will enhance our ability to create a long-term management plan.

CONSERVATION PLANS FOR OTHER SPOTTED OWL SUBSPECIES

Several conservation strategies have been developed for the other spotted owl subspecies. Perhaps the best known subspecies is the northern spotted owl of the Pacific Northwest and northwestern California. The northern subspecies was listed as threatened in June 1990, resulting in extensive conflict between conservation of the subspecies and economic and social interests of the Pacific Northwest, particularly the timber industry.

The first management strategy was initiated by the FS in the late 1970s. That approach, which continued within some portions of the subspecies' range until 1990, was to manage individual spotted owl territories, called Spotted Owl Habitat Areas (SOHAs), or, earlier, Spotted Owl Management Areas. Each SOHA consisted of certain acreages that varied according to location. Those territories were established according to certain clustering and spacing guidelines, and the general prescription for the territories was to restrict timber harvest so that a minimum "suitable habitat" acreage standard was maintained in the territories. However, in certain circumstances some harvest was allowed, such as salvage harvest.

In 1989, in response to increasing controversy over the spotted owl issue, the difficulty the issue was causing land-management agencies, and the proposed listing of the northern spotted owl as a threatened species, the Interagency Scientific Committee (ISC) was established. The

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ISC produced "A Conservation Strategy for the Northern Spotted Owl" (Thomas et al. 1990), which recommended significant changes in spotted owl management on public lands in the Pacific Northwest. Briefly, the ISC delineated large blocks of owl habitat, called Habitat Conservation Areas (HCAs). The goal was to delineate, where possible, HCAs known to support or with the potential to support at least 20 spotted owl pairs. However, where 20-pair HCAs were not possible, HCAs of 1 to 19 pairs were delineated. The HCAs were spaced certain distances from one another, depending on their sizes. The HCAs were to be managed so that no habitat degradation occurred within them, protecting existing habitat and allowing previously disturbed areas to return to a suitable condition. The ISC envisioned eventual HCAs where owl pairs could freely interact without significant disruption of habitat continuity between territories.

In addition, the ISC recommended managing the areas between HCAs, termed the "forest matrix," according to the "50-11-40 rule." This rule prescribed that at least 50% of the forested area within each quarter-township was to contain trees averaging a minimum of 28 cm (11 in) in diameter and with at least 40% crown closure. The idea was that these conditions would allow movement of owls between HCAs, thereby allowing genetic flow and demographic rescue of subpopulations. The ISC also recommended retention of 28-ha (70-acre) areas within the forest matrix to possibly provide future nesting/roosting sites.

In 1991, the Secretary of the Interior appointed the Northern Spotted Owl Recovery Team and charged it with developing a recovery plan for that subspecies. That recovery plan was closely modeled after the ISC plan. The HCA network was modified based on updated information, resulting in a network of Designated Conservation Areas (DCAs). Timber harvest in DCAs was generally not allowed in suitable habitat. Silvicultural treatments designed to encourage spotted owl habitat were limited to no more than 5% of a DCA in the first five years of plan implementation. Management recommendations for areas outside DCAs deviated from the ISC approach by providing greater justification for specific recommendations and consideration of economic efficiency of implementation.

The Northern Spotted Owl Recovery Plan was never implemented. Instead, the most recent management strategy for the northern spotted owl resulted from analyses and recommendations formulated by the Forest Ecosystem Management Assessment Team (FEMAT). The FEMAT was appointed by President Clinton to develop alternative plans for management of late-successional ecosystem components including, but not specific to, the northern spotted owl. Only Federal land management was addressed in the FEMAT alternatives.

The President selected "Option 9" developed by the FEMAT, which calls for a series of Late Successional Reserves (LSRs) corresponding roughly to the HCAs under the ISC plan. Outside the LSRs, the forest matrix includes Riparian Reserves (various sized buffers along class 1-3 streams); green-tree retention requirements (where 15% of each watershed is managed for late successional forest and at least 15% of each harvest unit is retained in the latest successional forest available); and preservation of 40 ha (100 ac) around all owl sites known as of 1 January 1994. The goal of this matrix prescription is to accommodate dispersing and "floater" owls, as well as other species dependent on old and mature forest conditions.

The FEMAT plan also establishes Adaptive Management Areas (AMAs) in California, Oregon, and Washington. These AMAs vary from less than 40,500 ha (100,000 ac) to nearly 200,000 ha (500,000 ac). The management objectives for each AMA also vary, but they are generally established to develop and test techniques for active forest management that provide a wide range of resource values including forest products, late-successional forest habitat, and high-quality recreation.

The range of the California spotted owl abuts the range of the northern subspecies in northeastern California, ranging south through the Sierra Nevada, west through the "transverse ranges" of Southern California, then north along the Coast Range to Monterey County. The California spotted owl was first managed by the FS using the SOHA system described for the northern subspecies. The portion of the subspe-

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cies' range in Southern California is still managed under that system while its effectiveness is assessed. However, the current management regime in the Sierra Nevada is described in the "Assessment of the Current Status of the California Spotted Owl, with Recommendations for Management" (Caspow Plan) (Verner et al. 1992b). The FS implemented the Caspow Plan on a temporary basis through an environmental assessment under the National Environmental Policy Act (NEPA) on 1 March 1993. The FS has since released a draft environmental impact statement under the NEPA that analyzes several alternatives for California spotted owl management, one of which is the Caspow Plan.

In the Sierra Nevada, the Caspow Plan recommends management emphasizing adequate amounts and distribution of suitable owl habitat through improved habitat and resource management practices rather than through protection of large blocks of habitat. The strategy seeks to protect known owl nest or roost sites, retain the larger and older components of forest structure, and address the problems of fire suppression and fuel loading. Additional objectives include rapidly recovering nesting and roosting habitat following disturbance, maintaining existing canopy layers, promoting tree growth by thinning in middle and lower canopy layers, and reducing vertical fuel ladders. Habitat available for timber management is classified by structural condition and utility for various life history requirements, and the resultant habitat classes are managed with restrictions on structural modifications. Long-term management proposals also focus on spotted owl nesting and roosting habitat as the target conditions for silvicultural activities.

To formulate the management strategy contained in this Recovery Plan, the Recovery Team examined the extensive efforts to protect the California and northern spotted owl subspecies. These efforts have, so far, experienced varying degrees of success and controversy. Moreover, the three subspecies exhibit differences in habitat use, habitat distribution, and threats. The Mexican Spotted Owl Recovery Plan combines, in the Recovery Team's opinion, the applicable recommendations from other planning efforts with those uniquely applicable to the Mexican subspecies.

ECOSYSTEM MANAGEMENT

The development of ecosystem management in the history of conservation plans for the northern spotted owl was described by Meslow (1993). Results of population and habitat research were incorporated into landscape designs involving reserves (HCAs) and interstitial matrices, both of which are basic attributes of landscape ecology (Diaz and Apostol 1993). Further considerations of the ecosystem management approach were extended to sympatric Federal- and State-listed species. It was clear that single-species management for the northern spotted owl would have numerous impacts on the many eligible but yet to be listed species (USDI 1992; Block et al. 1995). Thomas et al. (1993) described the relationship between the ISC plan for the northern spotted owl and the likelihood of viability for a suite of other species closely associated with late-successional forest. Verner et al. (1992) described numerous links between the California spotted owl and associated ecosystem components that it uses and requires to survive. Assessments of other species, such as northern goshawks (Reynolds et al. 1992) have also underscored the need to manage large landscapes to provide adequate prey and the diversity of habitats needed by those species.

Despite growing academic and professional awareness of the need to manage entire ecosystems, the Recovery Team is charged with development of a recovery plan for a single species. However, as the FWS and other land-management agencies move toward managing entire ecosystems, they are recognizing that single-species management will never protect all of the organisms that comprise the ecosystems upon which target species depend. Furthermore, a management plan for one species may conflict with a management plan for a sympatric species in absence of careful integration of the two plans. Block and Brennan (1993) noted that the management recommendations of the ISC for the northern spotted owl were firmly based in habitat management. In addition to habitat, however, both ecosystem-oriented and population-level considerations must be wed in conservation planning (Gutiérrez 1994).

The recovery team considered the interaction of populations, habitats, and ecosystems in the development of this Recovery Plan. The Recovery Team recognizes that numerous habitats exist within the range of the Mexican spotted owl and that not all of those habitats are important to the subspecies. The Recovery Team concentrated its management recommendations on habitats known to be important to the owl (see Parts II and III), while allowing other ecosystem management objectives, such as conservation of other species, to drive management of habitats where spotted owls are a secondary concern.

The Recovery Team believes that it is important to evaluate the effects of implementing Recovery Plan management recommendations on other endangered, threatened, sensitive, candidate, or other species of concern. In addition, it is important that the recommendations for Mexican spotted owl management be compared with the recommendations in other species' recovery or management plans. If conflicts are identified, they need to be resolved by appropriate land managers and/or scientists.

An important objective in management of forested ecosystems should be to address forest health problems, return forested ecosystems to conditions within their natural range of variation, and work toward sustainable and resilient ecosystems. The goals of this Recovery Plan and ecosystem management principles are compatible. Proper ecosystem management will provide for landscapes in which spotted owls and other ecosystem components persist within the range of their evolutionary adaptations. The metric used to measure progress should be the amount of acreage successfully treated to meet a desired result, and not commodity-based measures such as "board feet" or "animal unit months." Commodities will undoubtedly be a byproduct of forested ecosystem management, but should not be the driving consideration.

ECONOMIC CONSIDERATIONS

Protecting threatened and endangered species can conflict with other resource objectives. These conflicts can become more intense when species conservation efforts restrict economic returns from lands people depend upon for their livelihoods and communities depend upon for their very existence. Whether conflicts between species conservation and economic return are real or perceived, human concerns should be considered so long as the conservation goal is achieved.

As mentioned previously, the Recovery Team's charge was to develop a plan that would lead to recovery of the Mexican spotted owl. However, specific cause-effect relationships of many management activities on individual owls and pairs or in relation to population processes are not entirely clear. Given these uncertainties, it may be tempting to take a conservative approach to recovery by recommending cessation of all anthropogenic activities for which effects of the activity on the target species are poorly understood. However, recommendations for resource management should be based on established information. The absence of needed information should stimulate research, and the results of that research should guide management. The only way to understand the cause-and-effect relationships between management actions and specific resources is by studying them, preferably through controlled experiments.

The recommendations contained herein allow most land-management activities to occur provided that the effects of those activities are evaluated during the recovery period. In addition, the Recovery Plan recommends that scientific monitoring of the Mexican spotted owl population and its habitat should accompany those activities to assess their impact on spotted owl populations. If warranted, these activities can be altered or eliminated if monitoring or research indicates a significant risk to the spotted owl population. In other cases, restrictions on human activities are recommended where data show a high likelihood that the spotted owl's persistence may be significantly compromised if certain land-management practices continue.

Obviously, the decision on which activities must be altered or eliminated and which may proceed if closely monitored cannot be made with absolute certainty. Such decisions require professional judgement of the most qualified scientists using the best available data. The FWS selected the Recovery Team members with that fact in mind. However, the FWS also intends to use the expertise of others who may contribute useful information to improve management of the Mexican spotted owl.

Any conservation plan, regardless of species, must include the considerations discussed above when uncertainties exist. The FWS is confident that this Recovery Plan, given its inherent flexibility, has a high likelihood of leading to the recovery of the Mexican spotted owl without causing unacceptable levels of economic and social hardship during its implementation.

HUMAN INTERVENTION AND NATURAL PROCESSES

Much criticism directed at Mexican spotted owl management centers on the concept that today's southwestern forests are in an unnatural state; that grazing, fire suppression, forestry practices, and other anthropogenic processes have led to forest conditions much denser than those existing during presettlement times. A concurrent increase in mixed-conifer forests is also believed to have occurred. These points lead some to the conclusion that the Mexican spotted owl population is at an all-time (and unsustainable) high. The Recovery Team is unaware of data that clearly support that conclusion, and questions whether stands recently converted to mixed-conifer forest possess the structural characteristics utilized by the subspecies. The Recovery Team acknowledges that humans have had a pronounced influence on contemporary forest conditions; however, the effects of human activities on the Mexican spotted owl population are unknown. Even if one accepts that the spotted owl population in mixed-conifer forest is unnaturally high, one must also consider that other habitats that may have been important historically, such as lower- and middle-elevation riparian areas, have been dramatically reduced. These two trends may be offsetting, and the net gain or loss of spotted owl carrying capacity can only be speculated upon.

It would be imprudent, if not impossible, to develop a management plan for a species by speculating on its status in the distant past; rather, the appropriate approach is to acknowledge that we are dealing with a drastically altered landscape and that a return to presettlement conditions is impossible. In that light, the Recovery Team acknowledges that humans have a major role to play in management of the spotted owl and the forests of the Southwest. The Recovery Team believes that a viable forest-products industry is critical in carrying out the management actions recommended in this Recovery Plan, making it an essential agent of plan implementation.

DIFFERENCES BETWEEN THE DRAFT AND FINAL RECOVERY PLANS

The Recovery Team considered all comments received on the draft Mexican Spotted Owl Recovery Plan. In addition, the draft Recovery Plan underwent extensive peer review from both purposely selected reviewers and "blind" reviewers selected by certain scientific societies (see Appendix E). These reviews led to a final Recovery Plan that differs substantially from the draft version. We do not attempt to detail every difference between the two versions of the Recovery Plan, but discuss these differences in general terms.

Part II of the draft Recovery Plan contained a great deal of technical information. In the interest of making the Recovery Plan an easier document to use, several of those chapters were placed in a companion volume to this Recovery Plan. The information contained in those chapters was integral to Recovery Plan development, so the main points in each are summarized in Part II of this final Recovery Plan.

Part III has changed substantially from the draft version. Much of the background and justification discussion has been moved to Part II, so that the current Part III deals strictly with the management recommendations and delisting criteria. This allows land managers to more easily pull the specific recommendations out of the Part III text. In addition, the management recommendations have changed considerably, in that they are now in a more descriptive, rather than prescriptive, context. The changes were in response to comments from numerous land managers who expressed their concern that many of the tools available to achieve land-management objectives were overly constrained. The Recovery Team recognizes that the best approach is to describe the desired conditions on the landscape, while providing land-management professionals the flexibility to choose the tools to achieve the stated objectives.

The most significant change in Part IV is that the responsibility for implementing some of the tasks recommended in this Recovery Plan has been distributed among different entities. In addition, the estimated costs of implementing specific recovery tasks is provided.

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Biological and Ecological Background

Volume I, Part II

A. GENERAL BIOLOGY AND ECOLOGICAL RELATIONSHIPS OF THE MEXICAN SPOTTED OWL

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This section presents a summary of Volume 2, which examines aspects of the biology and ecological relationships of Mexican spotted owls in more detail. This is not an exhaustive treatment of the owl's biology and ecology, but is intended to provide an overview of biological elements germane to recovering the Mexican spotted owl. Although gaps still exist, our understanding of the Mexican spotted owl's natural history has increased with recent research as well as data analyses accomplished by the Recovery Team.

A wealth of information exists for the northern and California spotted owls (Thomas et al. 1990, Bart et al. 1992, Verner et al. 1992a, Gutiérrez et al., 1995). Although different in some respects, many aspects of the owls' biology and ecology are similar among the three subspecies. Thus, where appropriate, information from these subspecies was used for comparison or where data were limited regarding the Mexican spotted owl.

TAXONOMY

Three species within the genus *Strix* occur north of Mexico: spotted *(S. occidentalis)*, barred *(S. varia)*, and great gray owls *(S. nebulosa)*. Mexican spotted, barred, and fulvous owls *(S. fulvescens)* occur in Mexico. The Mexican spotted owl *(S. o. lucida)* is one of three subspecies of spotted owl recognized by the American Ornithologists' Union (AOU) in its last checklist that included subspecies (AOU 1957:285). The other two subspecies are the northern *(S. o. caurina)* and the California spotted owl *(S. o. occidentalis)* (AOU 1957; Figure.II.A.1).

The Mexican subspecies was first described from a specimen collected at Mount Tancitaro, Michoacan, Mexico and named *Syrnium occidentale lucidum* (Nelson 1903). The spotted owl was later assigned to the genus *Strix* (Ridgway 1914) and the subspecific name was changed to *lucida* to conform to taxonomic standards. Monson and Phillips (1981) regarded the Mexican spotted owl in Arizona as *S. o. huachucae*, noting that they were paler than *S. o. lucida*. However, this taxonomic designation was not followed by the AOU (1957).

The Mexican subspecies is geographically isolated from both the California and northern subspecies. Using electrophoresis to examine allozyme variation, Barrowclough and Gutiérrez (1990) found a major allelic difference between the Mexican spotted owl and the two coastal subspecies. This difference suggests that the Mexican spotted owl has been isolated genetically from the other subspecies for considerable time, has followed a separate evolutionary history, and could therefore be considered a separate species (Barrowclough and Gutiérrez 1990:742).

Northern spotted owls are known to hybridize with barred owls. Hybrids have been found in Washington and Oregon (Hamer et al. 1992), and in California (Alan Franklin, Humboldt State Univ., Arcata, CA, pers. comm.). The hybrids can be identified by their plumage, vocalizations, and morphology (Hamer et al. 1992). Closely related species occasionally hybridize naturally, especially where habitat disruption has led to contact between species previously isolated geographically (Short 1965, 1972). Hybridization has not been reported in the Mexican subspecies. The possibility of hybridization exists in Mexico where barred owls, fulvous owls, and spotted owls overlap in distribution. No evidence currently exists documenting actual sympatry among these species, however.

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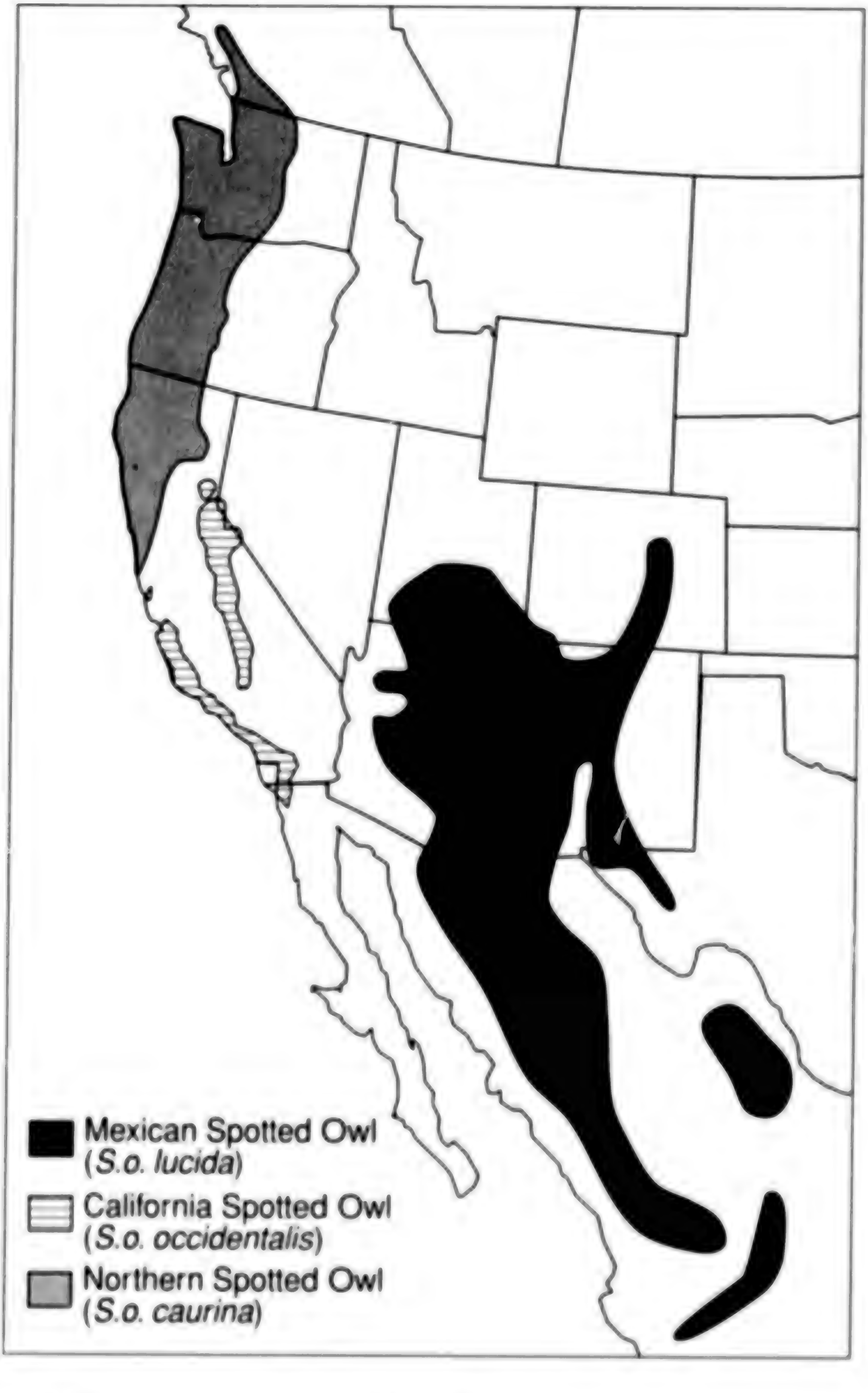
Figure II.A.1. Geographic range of the spotted owl.



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DESCRIPTION

The spotted owl is mottled in appearance with irregular white and brown spots on its abdomen, back, and head. The spots of the Mexican spotted owl are larger and more numerous than in the other two subspecies, giving it a lighter appearance. *Strix occidentalis* translates as "owl of the west" and *lucida* means "light" or "bright." Unlike most owls, spotted owls have dark eyes. Several thin white bands mark an otherwise brown tail.

Adult male and female spotted owls are mostly monochromatic in plumage characteristics, but the sexes can be readily distinguished by voice (see below). Juveniles, subadults, and adults can be distinguished by plumage characteristics (Forsman 1981, Moen et al. 1991). Juvenile spotted owls (hatchling to approximately five months) have a downy appearance. Subadults (5 to 26 months) closely resemble adults, but have pointed retrices with a pure white terminal band (Forsman 1981, Moen et al. 1991). The retrices of adults (>27 months) have rounded tips, and the terminal band is mottled brown and white.

Although the spotted owl is often referred to as a medium-sized owl, it ranks among the largest owls in North America. Of the 19 species of owls that occur in North America, only 4 are larger than the spotted owl (Johnsgard 1988). Like many other owls, spotted owls exhibit reversed sexual dimorphism (i.e., females are larger than males). Adult male Mexican spotted owls ($n = 37$) average 519 ± 32.6 (SD) g (18.5 oz), and adult females ($n = 31$) average 579 ± 31.2 g (20.7 oz) (Kristan et al., in prep.). There appears to be clinal variation among the three subspecies in a number of morphological characteristics measured, with size decreasing from north to south (Kristan et al., in prep.).

DISTRIBUTION AND ABUNDANCE

The Recovery Team gathered and examined information on the distribution and abundance of Mexican spotted owls through 1993. Data from surveys conducted after 1993 were not available for our analyses.

We used the information collected to (1) document historical and current range of this subspecies, (2) help formulate Recovery Unit boundaries, and (3) provide a template for analyses at the landscape scale. Descriptions of Recovery Units are provided in the following chapter (II.B).

The Mexican spotted owl currently occupies a broad geographic area, but does not occur uniformly throughout its range (Figure II.A.2). Instead, the owl occurs in disjunct localities that correspond to isolated mountain systems and canyons. In the United States, 91% of the owls known to exist between 1990 and 1993 occur on lands administered by the FS (Table II.A.1). Other lands currently occupied by Mexican spotted owls in the United States include, NPS (4%), BLM (2%), Tribal (2%), and DOD (1%). We know that more owls occur on Tribal lands than indicated here, but specific information on numbers of owls known on Tribal lands was not made available to the Team. Owl distribution according to land ownership is unavailable for Mexico. Eighty-nine percent of the owls known to exist between 1990 and 1993 in Mexico were in the States of Sonora and Chihuahua (Table II.A.1, Figure II.A.3). However, most survey efforts in Mexico were restricted to these states, and these numbers do not necessarily reflect actual trends in distribution.

The current owl distribution mimics its historical extent, with a few exceptions. The owl has not been reported recently along major riparian corridors in Arizona and New Mexico, nor in historically documented areas of southern Mexico. Riparian communities and previously occupied localities in the southwestern United States and southern Mexico have undergone significant habitat alteration since the historical sightings (USDI 1993). However, the amount of effort devoted to surveying these areas is unknown and future surveys may document spotted owls there. Surveys conducted to relocate spotted owls in northern Colorado near Fort Collins and Boulder, where records exist from the early 1970s and 1980s, have been unsuccessful. Surveys conducted in the Book Cliffs of east-central Utah, where owls were recorded in 1958, have also been unsuccessful. Although historical (pre-1990) data provide some information about

Figure II.A.2. Current distribution of Mexican spotted owls in the United States based on planned surveys and incidental observations recorded from 1990 through 1993.

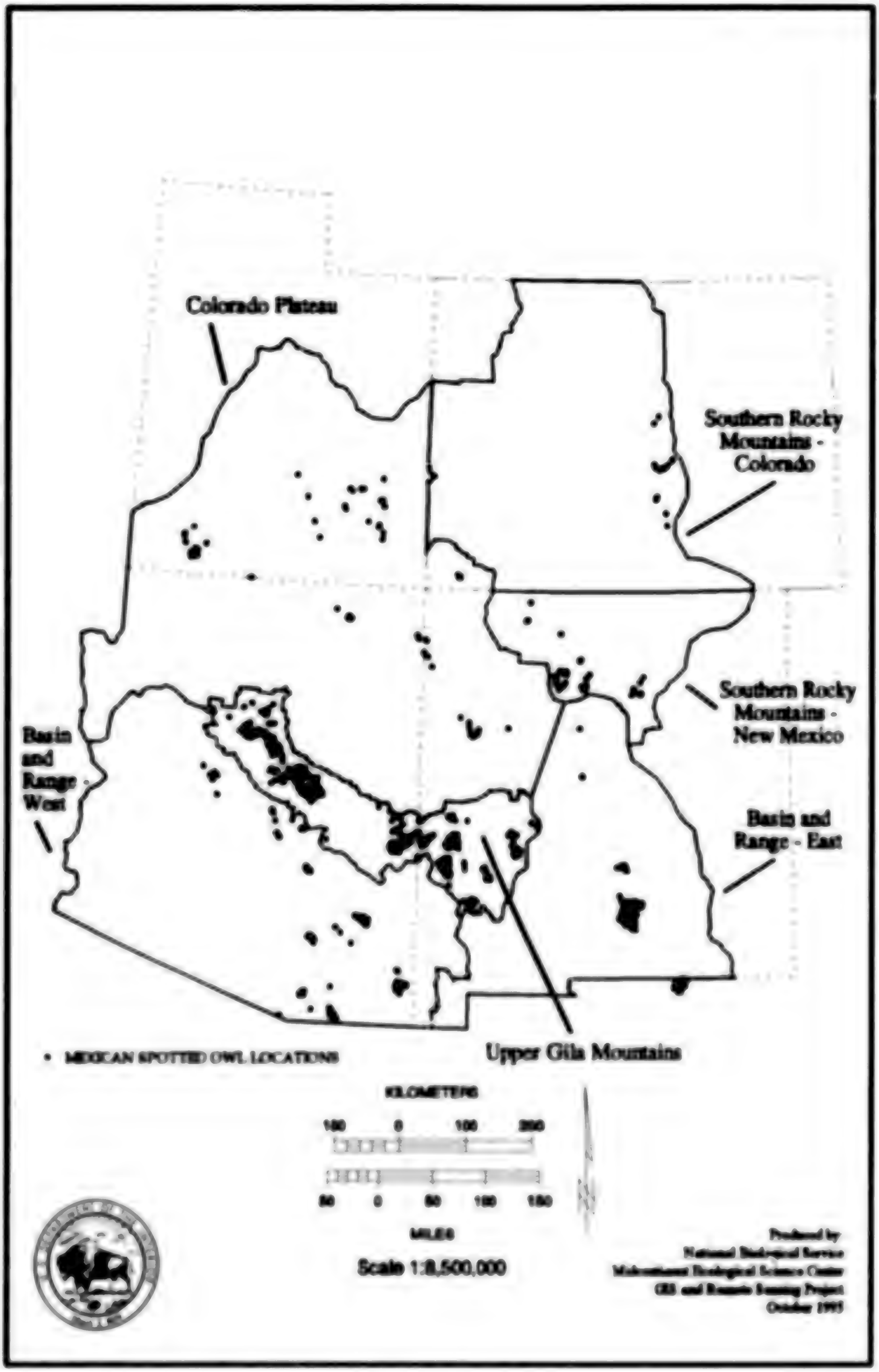

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Table II.A.1. Historical records and minimum numbers of Mexican spotted owls found during planned surveys and incidental observations, reported by Recovery Unit and land ownership. Recovery Units are described in Part II.B.

Recovery Unit	Number of[1] owl records before 1990	Number of owl sites 1990-1993
UNITED STATES		
Colorado Plateau		
FS	21	16
BLM	6	10
NPS	34	23
Tribal	20	13
New Mexico State	1	0
Unknown[1]	5	0
Subtotal	**87**	**62**
Southern Rocky Mountains – Colorado		
FS	2	8
BLM	0	6
NPS	0	0
Tribal	1	--[2]
Unknown[1]	17	0
Subtotal	**20**	**14**
Southern Rocky Mountains – New Mexico		
FS	25	34
NPS	3	0
New Mexico State	1	0
Private	4	0
Unknown[1]	8	0
Subtotal	**41**	**34**
Upper Gila Mountains		
FS	138	424
BLM	5	0
NPS	5	0
Tribal	0	--[2]
Private	1	0
Unknown[1]	104	0
Subtotal	**253**	**424**
Basin and Range – West		
FS	82	97
NPS	13	0
Tribal	0	--[2]
DOD	9	6
Private	8	0
Unknown[1]	57	0
Subtotal	**169**	**103**

Table II.A.1. continued

Recovery Unit	Number of[1] owl records before 1990	Number of owl sites 1990-1993
Basin and Range – East		
FS	18	111
BLM	1	0
NPS	6	10
Tribal	2	--[2]
FWS	1	0
Private	2	0
Subtotal	**30**	**121**
United States Total	**600**	**758**
MEXICO		
Sierra Madre Occidental – Norte		
Sonora	8	9
Chihuahua	10	8[4]
Subtotal	**18**	**17**
Sierra Madre Oriental – Norte		
Coahuila	2	0
Sierra Madre Occidental – Sur		
Sinaloa	1	0
Durango	2	0
Aguacalientes	0	1[4]
Zacatecas	0	0[4]
San Luis Potosi	1	0
Guanajuato	1	0
Subtotal	**5**	**1**
Sierra Madre Oriental – Sur		
Coahuila	4	0
Nuevo Leon	4	1
Tamaulipas	0	0[4]
Subtotal	**8**	**1**
Eje Neovolcanico		
Jalisco	1	0
Colima	1[5]	0
Michoacan	1	0
Puebla	1[5]	0
Subtotal	**2**	**0**
Mexico Total	**35**	**19**

[1] These values do not necessarily indicate numbers of owls or owl sites because multiple records may exist from the same site through time

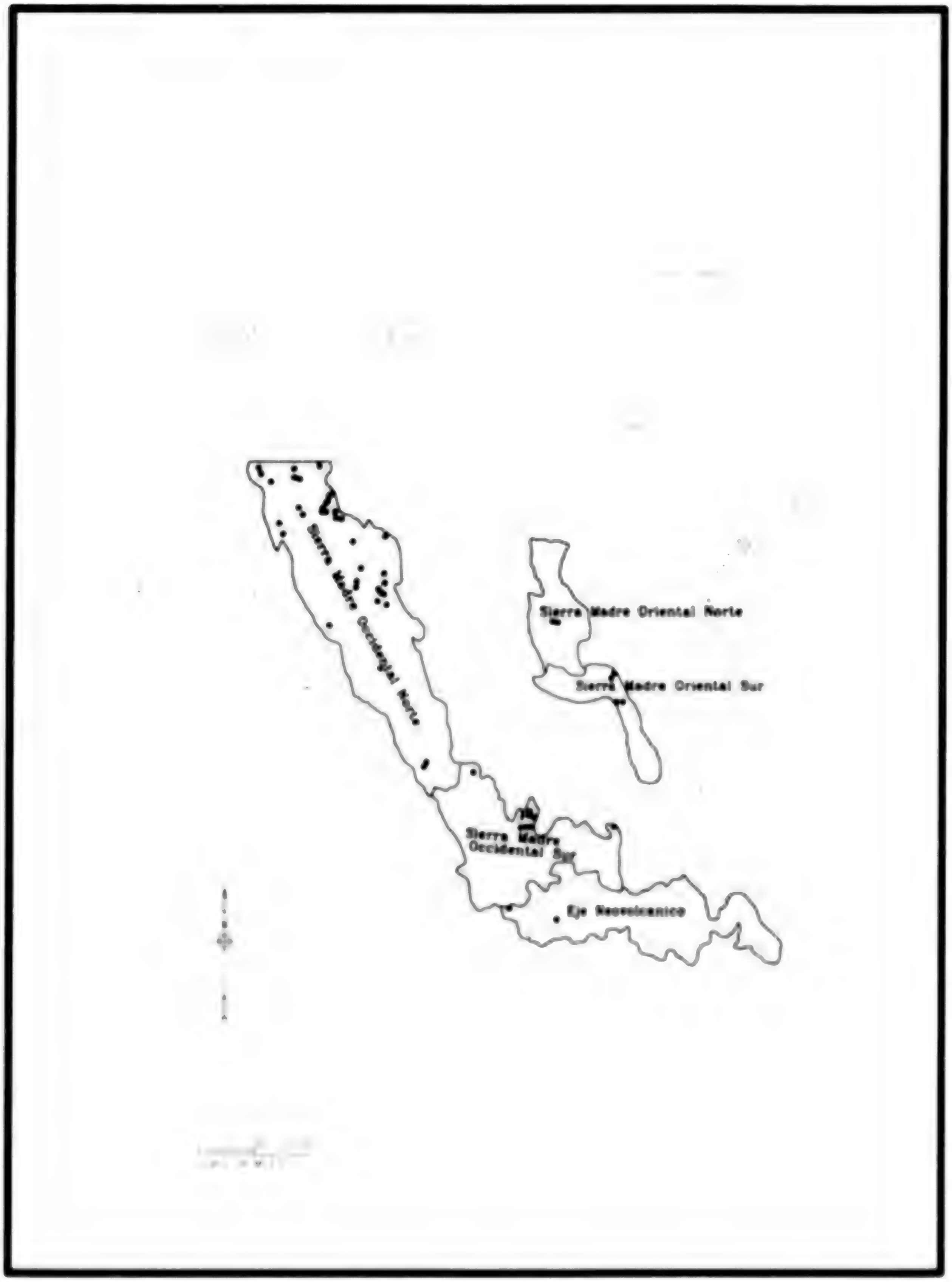
[2] Additional owls are known to exist on many Tribal lands, but the exact number is unavailable

[3] Locations of these records were insufficient for assigning a land ownership

[4] Additional sightings have been reported from 1994 surveys

[5] Unverified record not included in totals (see text)

Figure II.A.3. Current distribution of Mexican spotted owls in Mexico based on planned surveys and incidental observations recorded from 1990 through 1993.


Sierra Madre Occidental Norte
Sierra Madre Oriental Norte
Sierra Madre Oriental Sur
Sierra Madre Occidental Sur
Eje Neovolcanico

about past distribution of spotted owls, we stress that it is not sufficient to allow us to estimate changes in the number or distribution of owls from historical to present time.

Most current observations of Mexican spotted owls are from the Upper Gila Mountains RU (see II.B). This unit can be considered a critical nucleus for the subspecies because of its central location within the owl's range and its seemingly high number of owls. Other areas likely to be important population centers include the sky islands of southeastern Arizona and the Sacramento Mountains of central New Mexico (Basin and Range RUs; see II.B). Although information on owl numbers permits a view of the current distribution, it is not complete enough to provide a reliable estimate of total population size.

Mexican spotted owls occur at higher densities in mixed-conifer forests than in pine-oak, pine, and pinyon-juniper forest types (Skaggs and Raitt 1988, White et al. 1995). A combined estimate of Mexican spotted owl density on two study areas in the Upper Gila Mountains RU is similar to estimates reported for other spotted owl subspecies.

In summary, the Mexican spotted owl is distributed discontinuously throughout its range, with its distribution largely restricted to montane forests and canyons. Although future efforts will undoubtedly discover additional owls, their documented spatial distribution in the United States is not likely to change greatly. The converse is true for Mexico, where planned surveys have begun only recently.

HABITAT ASSOCIATIONS

Mexican spotted owls nest, roost, forage, and disperse in a diverse array of biotic communities. Mixed-conifer forests are commonly used throughout most of the range (Johnson and Johnson 1985, Skaggs and Raitt 1988, Ganey et al. 1988, Ganey and Balda 1989a, Rinkevich 1991, Willey 1993, Fletcher and Hollis 1994, Seamans and Gutiérrez, in press). In general, these forests are dominated by Douglas-fir and/or white fir, with codominant species including southwestern white pine, limber pine, and ponderosa pine (Brown et al. 1980). The understory often contains the above coniferous species as well as broadleaved species such as Gambel oak, maples, boxelder, and New Mexico locust. In southern Arizona and Mexico, Madrean pine-oak forests are also used commonly (Ganey and Balda 1989a, Duncan and Taiz 1992, Ganey et al. 1992, Tarango et al. 1994). These forests are typically dominated by an overstory of Chihuahua and Apache pines in conjunction with species such as Douglas-fir, ponderosa pine, and Arizona cypress. Evergreen oaks are typically prominent in the understory (Brown et al. 1980).

Habitat-use patterns vary throughout the range and with respect to owl activity (see below). In the northern portion of the range, including southern Utah, southern Colorado, and far northern Arizona and New Mexico, owls occur primarily in steep-walled, rocky canyons (Kertell 1977, Reynolds 1990, Rinkevich 1991, Willey 1993). Along the Mogollon Rim in Arizona and New Mexico, habitat use is less restricted, and spotted owls occur in mixed-conifer forests, ponderosa pine-Gambel oak forests, rocky canyons, and associated riparian forests (Ganey and Balda 1989a, Ganey et al. 1992, Fletcher and Hollis 1994, Seamans and Gutiérrez, in press, Peter Stacey, Univ. of Nevada, Reno, pers. comm.). South of the Mogollon Rim and into Mexico a still wider variety of habitat types are used, including mixed-conifer, Madrean pine-oak, and Arizona cypress forests, encinal oak woodlands, and associated riparian forests (Ganey and Balda 1989a, Duncan and Taiz 1992, Ganey et al. 1992, Tarango et al. 1994). Much of this regional variation in habitat use likely results from differences in regional patterns of habitat and prey availability.

Nesting and Roosting Habitat

Mexican spotted owls nest and roost primarily in closed-canopy forests or rocky canyons. In the northern portion of the range (southern Utah and Colorado), most nests are in caves or on cliff ledges in steep-walled canyons. Elsewhere, the majority of nests appear to be in trees (Fletcher and Hollis 1994).

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Forests used for roosting and nesting often contain mature or old-growth stands with complex structure (Skaggs and Raitt 1988, Ganey and Balda 1989a, 1994; McDonald et al. 1991, Seamans and Gutiérrez, in press). These forests are typically uneven-aged, multistoried, and have high canopy closure. Nest trees are typically large in size (SWCA 1992, Fletcher and Hollis 1994, Seamans and Gutiérrez, in press), whereas owls roost in both large and small trees (Ganey 1988, Rinkevich 1991, Willey 1993, Zwank et al. 1994, Peter Stacey, Univ. of Nevada, Reno, pers. comm.). Tree species used for nesting vary somewhat among areas and habitat types, but available evidence suggests that Douglas-fir is the most common species of nest tree (SWCA 1992, Fletcher and Hollis 1994, Seamans and Gutiérrez, in press). A wider variety of trees are used for roosting, but again Douglas-fir is the most commonly used species (Ganey 1988, Fletcher and Hollis 1994, Zwank et al. 1994, Peter Stacey, Univ. of Nevada, Reno, pers. comm.).

Several hypotheses have been proposed to explain why spotted owls nest in closed-canopy forests (reviewed by Carey 1985, Gutiérrez 1985). Barrows (1981) suggested that spotted owls are relatively intolerant of high temperatures and roost and nest in shady forests because they provide favorable microclimatic conditions. Ganey et al. (1993) observed that Mexican spotted owls produced more metabolic heat than great horned owls, and were less able to dissipate that heat. This may lead these owls to seek out cool microsites during periods of high ambient temperature. Mexican spotted owls typically nest and roost in closed-canopy forests or deep shady canyons; both situations provide cool microsites (Kertell 1977, Ganey et al. 1988, Rinkevich 1991, Ganey and Balda 1989a, Willey 1993).

Foraging Habitat

Little is known about patterns of habitat use by foraging owls. The only available data describe habitat use by eight owls occupying five home ranges on three study areas in northern Arizona (Ganey and Balda 1994). In general, owls foraged more than or as expected in unlogged forests, and less than or as expected in selectively logged forests. Expected values were based on relative occurrences of habitats. However, patterns of habitat use varied among study areas and individuals, and even between pair members in some cases, making generalizations difficult. Both high-use roosting and high-use foraging sites had more big logs, higher canopy closure, and greater densities and basal areas of both trees and snags than random sites. Owls clearly used a wider variety of forest conditions for foraging than they used for roosting (Ganey and Balda 1994). We caution, however, about extending these results too far given the limited number of owls sampled, and the variability observed among owls and sites.

TERRITORIALITY AND HOME RANGE

Home range is defined as the area used by an animal during its normal activities (Burt 1943) whereas *territory* is a defended area within an individual's home range (Nice 1941). Territories are typically smaller than home ranges, but the exact relationship between the territory and the home range is generally not known. Fidelity to territories is apparently high in Mexican spotted owls, with most owls remaining on the same territory year after year.

Home-range size of Mexican spotted owls, as estimated by monitoring movements of radiotagged owls, appears to vary considerably among habitats and/or geographic areas (Ganey and Dick 1995). Differences in sampling methods among studies make comparisons difficult, however. Minimum convex polygon home range estimates of home range-size varied from (1) 924 - 1,487 ha (2,282 - 3,672 acres) for individuals (n = 11) on three study areas in Colorado Plateau RU (Willey 1993); (2) 261 - 1,053 ha (645 - 2,601 acres) for individuals (n = 25) and 381 - 1,551 ha (941 - 3,831 acres) for pairs (n = 10) on five study areas in the Upper Gila Mountains RU (Ganey and Balda 1989b, Ganey and Block, unpublished data, Peter Stacey, Univ. of Nevada, Reno, pers. comm.); and (3) 452 - 937 ha (1,116 - 2,314 acres) for individuals (n = 20) and 573 - 1,401 ha (1,415 - 3,461 acres) for pairs (n = 8) on two study areas in the Basin and Range-East RU

(Zwank et al. 1994, Ganey and Block, unpublished data).

VOCALIZATIONS

The spotted owl, being primarily nocturnal, is more often heard than seen. It has a wide repertoire of calls (Forsman et al. 1984, Ganey 1990) that are relatively low-pitched and composed of pure tones (Fitton 1991). Sexes can be distinguished by calls; males have a deeper voice than females and generally call more frequently. The most common vocalization, used more often by males, is a series of four unevenly-spaced hoots. Females frequently use a clear whistle ending with an upward inflection as well as a series of sharp barks. Forsman et al. (1984) described 14 calls for the northern spotted owl, of which 10 were reported by Ganey (1990) for Arizona birds.

Mexican spotted owls call mainly from March - November and are relatively silent from December - February (Ganey 1990). Calling activity increases from March through May (although nesting females are largely silent during April and early May), and then declines from June through November (Ganey 1990). On a daily basis, calling activity is greatest during the 2-hour period following sunset, with smaller peaks 4-8 hours after sunset and just before sunrise. Owls called more than expected during the last quarter and new moon phases of the lunar cycle; and they called most frequently on calm, clear nights when no precipitation was falling (Ganey 1990).

INTERSPECIFIC COMPETITION

Several other species of owls occur within the range of the Mexican spotted owl. Interference competition, where individuals physically interfere with each other, probably does not occur to any great extent between the Mexican spotted owl and other owl species. However, exploitative competition, where individuals compete for similar resources such as prey or nest sites, may occur. Competition might be greatest between spotted and great horned owls because both species are relatively large and widely distributed. Preliminary data from a telemetry study in northern Arizona suggest that these owls overlap broadly in diet and space, but exhibit some habitat segregation (Ganey and Block, unpublished data). If Mexican spotted and barred owls are sympatric in Mexico, then competition might also occur between these closely related species. In general, however, more research is needed to assess the potential occurrence and importance of interspecific competition between spotted and other owls.

FEEDING HABITS AND PREY ECOLOGY

Forsman (1976) described spotted owls as "perch and pounce" predators. They typically locate prey from an elevated perch by sight or sound, then pounce on the prey and capture it with their talons. Spotted owls have also been observed capturing flying prey such as birds and insects (Verner et al. 1992b). They hunt primarily at night (Forsman et al. 1984, Ganey 1988), although infrequent diurnal foraging has been documented (Forsman et al. 1984, Laymon 1991, Sovern et al. 1994).

Mexican spotted owls consume a variety of prey throughout their range but commonly eat small- and medium-sized rodents such as woodrats, peromyscid mice, and microtine voles. Spotted owls also consume bats, birds, reptiles, and arthropods. The diet varies by geographic location (Ward and Block 1995; Figure. II.A.4). For example, spotted owls dwelling in canyons of the Colorado Plateau take more woodrats, and fewer birds, than do spotted owls from other areas (Ward and Block 1995, Figure. II.A.4). In contrast, spotted owls occupying mountain ranges with forest-meadow interfaces, as found within the Basin and Range - East, Southern Rocky Mountains - Colorado, and Upper Gila Mountains RUs, take more voles (Ward and Block 1995, Figure. II.A.4). Regional differences in the owl's diet likely reflect geographic variation in population densities and habitats of both the prey and the owl.

The Team was unable to link consumption of specific prey and successful reproduction by the Mexican spotted owl, with two possible exceptions. First, fecundity of spotted owls occupying the Sacramento Mountains (Basin and Range - East RU) appeared to be associated with trends in abundance of peromyscid mice (Ward and Block 1995). Second, the predominance of woodrats in the diet throughout much of the owl's range suggests that this prey may influence the owl's fitness. Other studies have shown positive associations between larger prey (e.g., woodrats) in the diet of northern and California spotted owls and their reproductive success (Barrows 1987, Thrailkill and Bias 1989). In most cases, however, total prey biomass may be more influential on the owl's fitness than the abundance of any particular prey species.

Habitat correlates of the owl's common prey emphasize that each prey species uses a unique microhabitat. For example, deer mice are ubiquitous in distribution, occupying areas with variable conditions, whereas brush mice are restricted to communities with a strong oak component and dry, rocky substrates with sparse tree cover. Mexican woodrats are typically found in areas with considerable shrub or understory tree cover, little herbaceous cover, and high log volumes. Mexican voles are found in areas with high herbaceous cover, primarily grasses. Long-tailed voles are associated with high herbaceous cover, primarily forbs, many shrubs, and limited tree cover. Thus, to provide a diverse prey base, managers should provide diverse habitats for prey species. Managing habitat for a diversity of prey species may help buffer against population fluctuations of individual prey species and provide a more constant food supply for the owl.

REPRODUCTIVE BIOLOGY

Knowledge of the annual reproductive cycle of the Mexican spotted owl is important both in an ecological context, and for placing seasonal restrictions on management or on other activities that may occur within areas occupied by spotted owls. Data on the reproductive cycle of the Mexican spotted owl are limited compared to information on the northern and California subspecies. Therefore, although the following discussion is based primarily on observations of the Mexican spotted owl, data from the other subspecies are provided to fill some information gaps.

Mexican spotted owls nest on cliff ledges, stick nests built by other birds, debris platforms in trees, and in tree cavities (Johnson and Johnson 1985, Ganey 1988, SWCA 1992, Fletcher and Hollis 1994, Seamans and Gutiérrez, in press). Spotted owls have one of the lowest clutch sizes among North American owls (Johnsgard 1988). Females normally lay one to three eggs, two being most common. Renesting following nest failure is unusual, but has been observed in Mexican spotted owls (Kroel 1991, David Olson, Humboldt State Univ., Arcata, CA, pers. comm.). Mexican spotted owls breed sporadically and do not nest every year (Ganey 1988). In good years most of the population will nest, whereas in other years only a small proportion of pairs will nest successfully (Fletcher and Hollis 1994). Reasons for this pattern are unknown.

Mexican spotted owls have distinct annual breeding periods, but reproductive chronology varies somewhat across the range of the owl. In Arizona, courtship apparently begins in March with pairs roosting together during the day and calling to each other at dusk (Ganey 1988). Eggs are laid in late March or, more typically, early April. Incubation begins shortly after the first egg is laid, and is performed entirely by the female (Ganey 1988). Female northern spotted owls incubate for approximately 30 days (Forsman et al. 1984), and Mexican spotted owls appear to incubate for a similar period (Ganey 1988). During incubation and the first half of the brooding period, the female leaves the nest only to defecate, regurgitate pellets, or to receive prey delivered by the male, who does most or all of the foraging (Forsman et al. 1984, Ganey 1[illegible]

The eggs usually hatch in early May (Ganey 1988). Females brood their young almost constantly for the first couple of weeks after the eggs hatch but then begin to spend time hunting at night, leaving the owlets unattended for up to several hours (Eric Forsman, FS, Corvallis, OR, pers. comm.). Nestling owls generally fledge four to five weeks after hatching in early to mid-June (Ganey 1988). Owlets usually leave the nest before they can fly, jumping from the nest on to surrounding tree branches or the ground (Forsman et al. 1984, Ganey 1988). Owlets that

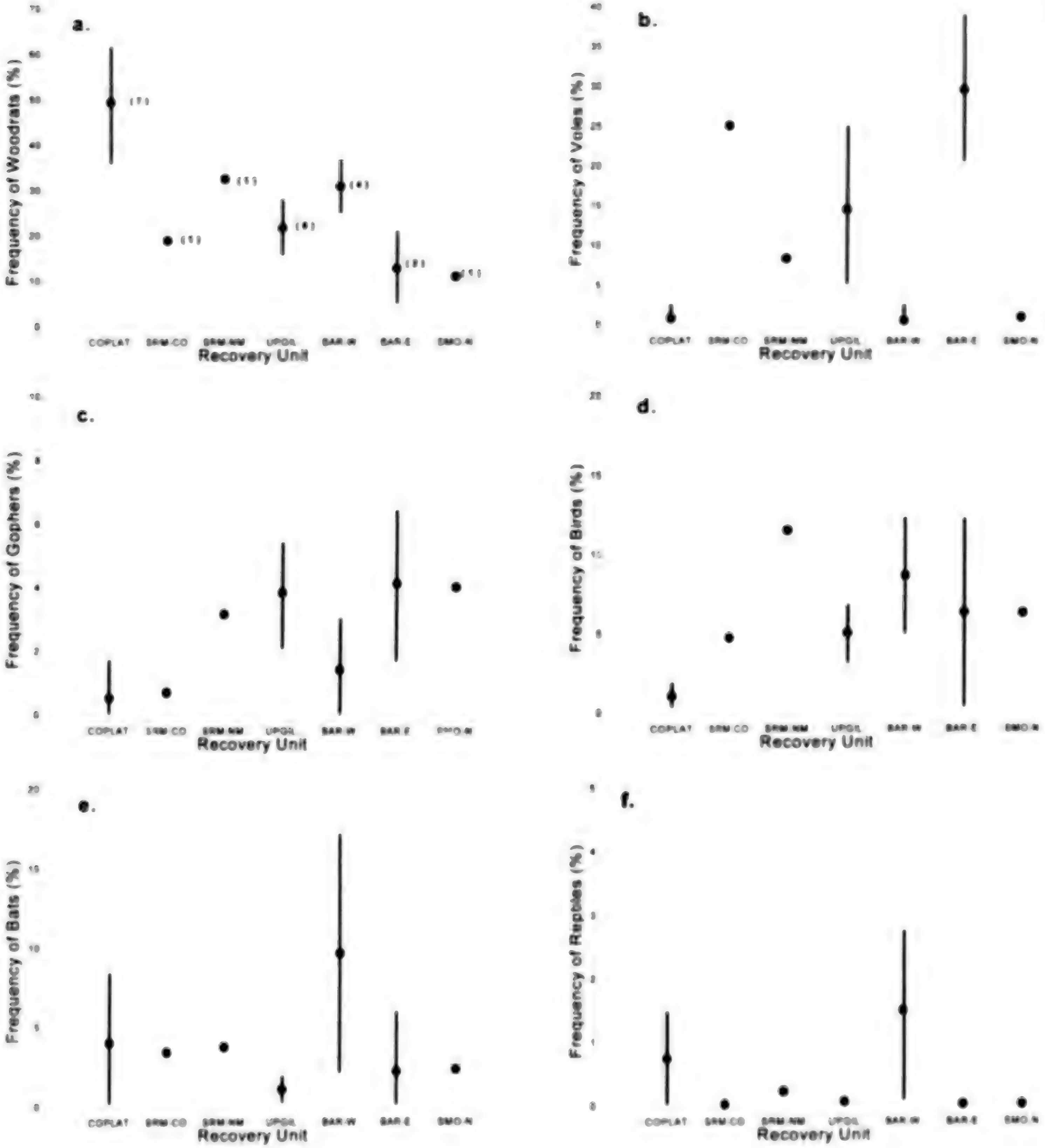

Figure II.A.4. Geographic variability in the food habits of Mexican spotted owls presented as relative frequencies of **(a)** woodrats, **(b)** voles, **(c)** gophers, **(d)** birds, **(e)** bats, and **(f)** reptiles. Point values are from single studies or averages among the number of studies shown in parenthesis **(a)**. Vertical bars are 95% confidence intervals showing sampling and interstudy variation within a recovery unit. Recovery unit acronyms are COPLAT-Colorado Plateau; SRM-CO-Southern Rocky Mountain-Colorado; SRM-NM-Southern Rocky Mountain-New Mexico; UPGIL-Upper Gila Mountain; BAR-W-Basin and Range - West; BAR-E-Basin and Range - East; SMO-N-Sierra Madre Occidental-Norte.

end up on the ground will often climb back up a tree to a safe roost site. The mobility and foraging skills of owlets improve gradually during the summer. Within a week after leaving the nest, most owlets can make short, clumsy flights between trees. Three weeks after leaving the nest, owlets can hold and tear up prey on their own (Forsman et al. 1984).

Fledglings depend on their parents for food during the early portion of the fledgling period. Hungry owlets give a persistent, raspy "begging call," especially when adults appear with food or call nearby (Forsman et al. 1984, Ganey 1988). Begging behavior declines in late August, but may continue at low levels until dispersal occurs, usually from mid September to early October (Ganey and Block, unpubl. data, Peter Stacey, Univ. of Nevada, Reno, pers. comm., David Willey, Northern Arizona Univ., Flagstaff, pers. comm.).

MORTALITY FACTORS

Several mortality factors (discussed below) have been identified as potentially important with respect to the Mexican spotted owl. Although a number of owls have been recovered following mortality and examined by both field biologists and laboratory personnel, in general little is known about the extent or importance of these mortality factors.

Predation

Predation, particularly by avian predators, may be a common mortality factor of spotted owls. Potential avian predators of Mexican spotted owls include great horned owls, northern goshawks, red-tailed hawks, and golden eagles. Some of these predators occupy the same general habitats as the spotted owl, but there is little direct evidence that they prey on spotted owls to any great extent (Gutiérrez et al. 1995). Ganey (1988) reported one instance of apparent great horned owl predation on an adult spotted owl, and Richard Reynolds (FS, Fort Collins, CO., pers. comm.) reported a golden eagle preying on a spotted owl. Preliminary results from radio-tagged Mexican spotted owls indicate that both adults and juveniles are preyed upon (Willey 1993, Ganey and Block, unpubl. data), but in most cases the identity of the predator was unknown. Further, in southern Arizona, procyonid mammals were observed attempting to raid cliff site nests occupied by spotted owls (Russell Duncan, Southwestern Field Biologists, Tucson, AZ, pers. comm.). Thus, the extent to which Mexican spotted owls are preyed upon is unknown at this time.

Starvation

Starvation is likely another common source of mortality. Juvenile northern spotted owls may be more vulnerable to starvation than adults (Gutiérrez et al. 1985, Miller 1989), because of their poor hunting skills. Starvation may also result from low abundance or availability of prey, which could affect both adults and juveniles. Both adult and juvenile owls radio-tagged in Arizona have been found dead of apparent starvation (Ganey and Block, unpublished data), and two of seven radio-tagged juveniles in Utah died of starvation (Willey 1993). Most instances of starvation occurred from late fall through winter, when prey resources were reduced in abundance and availability (Willey 1993, Block and Ganey, unpublished data). In addition, starvation may predispose young or even adults to predation.

Accidents

Accidents may be another mortality factor. For example, instances of spotted owls being hit by cars have been documented (Roger Skaggs, New Mexico State Univ, Las Cruces, pers. comm; Russell Duncan, Southwestern Field Biologists, Tucson, AZ, pers. comm.). Owls flying at night might also collide with powerlines, tree branches, or other obstacles. This might be particularly true for birds migrating or dispersing through unfamilar terrain. Again, little information is available on how frequently this might occur.

Disease and Parasites

Little is known about how disease and parasites contribute to mortality of spotted owls. Hunter et al. (1994) found a larval mite and lice on 2 of 28 museum specimens of Mexican spotted owls examined for parasites, and 6 of 18 live owls examined had hippoboscid fly larvae in their ears. Some of the live owls examined also had lice. Hunter et al. (1994) reached no conclusions concerning mortality and ectoparasites in spotted owls, but did suggest that larval infestations in their ears could affect the owls' hearing. Because hearing is important for foraging at night, such infestations could impact the birds' ability to hunt effectively.

In general, however, spotted owls may be adapted to high parasite loads. In a survey of blood parasites in all three subspecies of spotted owls, Gutiérrez (1989) found an infection rate of 100 percent. Although disease and parasites could predispose owls to death by starvation, predation, or accident, no evidence exists documenting disease and parasites as direct mortality factors within the Mexican subspecies.

POPULATION BIOLOGY

The Mexican Spotted Owl population for a specific area can be modeled with the simple equation

$$N_{t+1} = N_t + B_t - D_t + I_t - E_t ,$$

where N_t is the population size at time t, B_t is the number of new birds recruited into the population (births), D_t is the number of birds dying, I_t is the number of birds immigrating into the population, and E_t is the number of birds emigrating from the population. The combined effect of births, deaths, immigrations, and emigrations dictate the viability of the population, and hence its long-term persistence.

Survival

Annual survival rates of adult Mexican spotted owls is 0.8-0.9 based on short-term population and radio-tracking studies and longer-term monitoring studies (White et al. 1995). These annual survival estimates can be viewed as the probability of an individual surviving from one year to the next or as the proportion of individuals that will survive from one year to the next. A variety of different estimators of adult survival using different types and sets of data gave similar results.

Juvenile survival is considerably lower (0.06-0.29) than adult survival. Juvenile survival also appears more spatially variable, although this conclusion reflects only two population study areas and two radio-telemetry studies spanning two years or less.

We strongly suspect that estimates of juvenile survival from the population studies which utilize mark-recapture methods are biased low because of (1) a high likelihood of permanent dispersal (emigration) from the study area, and (2) a lag of several years before marked juveniles reappear as territory holders, at which point they are first detected for recapture. Juvenile northern spotted owls have a high dispersal capability (reviewed in Thomas et al. 1990). If Mexican spotted owl juveniles have a similar dispersal capability, we expect that a substantial portion of marked juveniles will emigrate from the respective study areas. However, estimates from the radio-telemetry studies roughly corroborated the low estimates from the population studies. Biases in the radio-telemetry estimates of juvenile survival can result if radios significantly affect their survival. Whether radios or their attachment affect survival of northern spotted owls is debatable (Paton et al. 1991, Foster et al. 1992). Concerning the second point, Franklin (1992) found a lag of 1-4 years between the time when juvenile northern spotted owls were banded and subsequently recaptured. If this process is similar for Mexican spotted owls, then the current population studies may be of insufficient duration to adequately estimate juvenile survival.

In summary, current survival estimates are based primarily on studies of insufficient duration or studies not explicitly designed to estimate survival. In most cases, the data are too limited to support or test the assumptions of the estimators used. However, the age- and sex-specific estimates of survival calculated here are useful at this point as qualitative descriptors of the life-history characteristics of Mexican spotted owls.

That is, Mexican spotted owls exhibit high adult and relatively low juvenile survival. In this respect, Mexican spotted owl survival probabilities appear similar to northern (see review in Burnham et al. 1994) and California spotted owls (Noon et al. 1992).

Reproduction

Reproductive output of Mexican spotted owls, defined as the number of young fledged per pair, varies both spatially and temporally (White et al. 1995). Mexican spotted owls may have a higher average reproductive rate (1.001 fledged young per pair) than the California (~0.712: Noon et al. 1992) and the northern spotted owl (~0.715; Thomas et al. 1993). All three subspecies exhibit temporal fluctuations in reproduction, although the amplitude of those fluctuations may be greatest for the Mexican spotted owl.

Environmental Variation

Environmental conditions greatly affect reproduction and/or survival of nestlings through fledging and to adulthood. However, adult survival rates appear to be relatively constant across years, as suggested by high pair persistence rates (White et al. 1995). Such life history characteristics are common for K-selected species, for which populations remain relatively stable even though recruitment rates might be highly variable. With no recruitment, the population declines at the rate of 1 minus adult survival, or the adult mortality rate.

Population Trends

We have inadequate data to estimate population trends in Mexican spotted owls. We have little confidence in our estimates of population trend that include estimates of juvenile survival because these estimates of juvenile survival are probably biased low. Further, the population studies from which parameter estimates were derived have not been conducted for a sufficiently long period to capture temporal variation. Population trend was also evaluated with occupancy data (White et al. 1995), but again is suspect. Changes in occupancy rate probably correspond more with how monitoring of owls was performed rather than reflecting true change in the owl population. As a complicating factor, a nonrandom sample of all existing Mexican spotted owl territories was monitored, thus limiting possible inferences.

MOVEMENTS

Seasonal Movements

Seasonal movement patterns of Mexican spotted owls are variable. Some radio-tracked owls are year-round residents within an area, some remain in the same general area but show shifts in habitat-use patterns, and some migrate considerable distances (20-50 km [12-31 miles]) during the winter (Ganey and Balda 1989b, Ganey et al. 1992, Willey 1993, Ganey and Block unpublished data). In general, migrating owls move to more open habitats at lower elevations (Ganey et al. 1992, Willey 1993). Willey (1993), however, observed one owl that migrated to coniferous forest at a higher elevation than the owls' breeding-season range.

Natal Dispersal

Little is known about habitat use by juveniles during natal dispersal. Seven juveniles radio-tracked in southern Utah (Willey 1993) dispersed over distances ranging from 24 to 145 km (15 to 90 miles). These owls apparently moved through a variety of habitats including spruce-fir and mixed-conifer forests, pinyon-juniper woodland, mountain shrublands, desert scrublands and desert grasslands. Another five juvenile owls were radio-tagged in the San Mateo Mountains of New Mexico in 1993 (Peter Stacey, Univ. of Nevada, Reno, pers. comm.). Two of these apparently moved to an adjacent mountain range before their signals were lost. Of the remaining three, one was relocated the following year within the San Mateo Mountains. Fates of the other two juveniles were unknown.

LANDSCAPE PATTERN AND METAPOPULATION STRUCTURE

Keitt et al. (1995) examined the spatial pattern of forest habitat patches across the range of the Mexican spotted owl. Their objective was to gauge the extent to which the owl might behave as a metapopulation in the classical sense of a set of local populations linked by infrequent dispersal. Such a finding, if verified, would suggest that population dynamics of owls in one local population might be influenced by factors, including management activities, that affected nearby populations. Conversely, if local populations are functionally discrete, then those populations could be treated separately with some confidence that actions in one part of the owl's range would not greatly affect other populations.

Keitt et al. (1995) concluded that the owl probably behaves as a classical metapopulation over much of its range. That is, the level of habitat connectivity is such that many habitats are "nearly connected" at distances corresponding to their best empirical estimates of the owl's dispersal capability. At this scale, the landscape consists of a set of large, more-or-less discrete habitat clusters. For example, most of the Mogollon Rim functions as a single cluster, the southern Rockies as another single cluster, and so on. This suggests that owls could disperse within habitat clusters with very high probability, and disperse between clusters at very low probability. Thus, we would expect owls to disperse within clusters most of the time but between clusters only rarely which is consistent with the definition of a metapopulation. This finding suggests that the Plan should incorporate recommendations that maintain (or increase) habitat connectivity across the owl's range. Habitat connectivity buffers a population from stochastic variability through time by providing the opportunity for local population failures to be "rescued" by immigration from other populations.

Keitt et al. (1995) also attempted to identify those habitat clusters most important to overall landscape connectivity. They first ranked habitats to emphasize the importance of large patches in the landscape, and second, they modified this approach to emphasize positional effects (i.e., small clusters that are important because they act as "stepping stones" or bridges between larger habitat clusters).

In the first analysis, the largely contiguous habitat of the Mogollon Rim emerged as most important overall, because of its large area. In the analysis emphasizing cluster position, a few small clusters emerged as particularly important. These included several fragments of the Cibola National Forest (Mt. Taylor and Zuni Mountains) that may serve as stepping stones between other, larger clusters. These small patches may warrant particular management attention; they may support few owls but may nevertheless be important to overall landscape connectivity.

CONCLUSIONS

In many ways, the Mexican spotted owl appears to be quite similar to both the northern and California spotted owls with respect to general behavioral patterns and ecology. For example, all three subspecies are most common in forests of complex structure, prey mainly on nocturnally-active small mammals, and share similar vocalizations, reproductive chronologies, and population characteristics. However, important differences exist between the Mexican spotted owl and the other subspecies. The distributional pattern of the Mexican spotted owl is more disjunct than that of the other subspecies, with the possible exception of the California spotted owl population in the mountain ranges of southern California (Noon and McKelvey 1992). The Mexican subspecies also appears to use a wider range of habitat types than the other subspecies. These unique aspects of the ecology of the Mexican spotted owl require unique approaches to its management. For example, threats to owl habitat and management proposed to address those threats may well differ among the diverse habitats occupied by Mexican spotted owls. In addition, because of its' disjunct distributional pattern, dispersal among subpopulations of Mexican spotted owls is an important consideration. Thus, habitat management plans may need to consider not only areas occupied by owls but also intervening areas, even where such areas are very different in habitat structure from those typically occupied by spotted owls.

We have learned a great deal about the Mexican spotted owl in the last decade, but significant information gaps still remain. Most studies of the owl to date have been descriptive rather than experimental (III.D). Although we have identified patterns with respect to some aspects of the owls' ecology (e.g. habitat use), cause and effect relationships have not been documented. Further, many aspects of spotted owl demography and population structure remain unclear. These considerations suggest that much additional research is needed, and that management recommendations in the near term must deal with high levels of uncertainty.

B. RECOVERY UNITS

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Frank P. Howe, Fernando Clemente, and Juan F. Martinez-Montoya

The Mexican spotted owl inhabits diverse forest types scattered across an even more physically diverse landscape. Further, human activities vary dramatically throughout the owl's range. These variations limit our ability to approach a status assessment on a rangewide basis. Consequently, we divided the range of the owl into 11 geographic areas called "Recovery Units" (hereafter RUs). Six RUs were recognized within the United States: Colorado Plateau, Southern Rocky Mountains - Colorado, Southern Rocky Mountains - New Mexico, Upper Gila Mountains, Basin and Range - West, and Basin and Range - East (Figure. II.B.1). Five RUs were recognized in Mexico: Sierra Madre Occidental - Norte, Sierra Madre Oriental - Norte, Sierra Madre Occidental - Sur, Sierra Madre Oriental - Sur, and Eje Neovolcanico (Figure. II.B.2).

UNITED STATES

Recovery Units were identified based on the following considerations (in order of importance): (1) physiographic provinces, (2) biotic regimes, (3) perceived threats to owls or their habitat, (4) administrative boundaries, and (5) known patterns of owl distribution. It is important to note that owl distributional patterns were a minor consideration in RU delineation, and that RUs do not necessarily represent discrete populations of owls. In fact, movement of individuals between RUs has been documented (Ganey and Dick 1995).

Four major physiographic provinces were used in delineating RUs in the United States: the Colorado Plateau, Basin and Range, Southern Rocky Mountains, and Upper Gila Mountains (Hammond 1965, Wilson 1962, USGS 1970, Bailey 1980). Biotic regimes were based on classifications by Bailey (1980) and Brown et al. (1980). Administrative boundaries were used where management practices differed between jurisdictions (e.g., Southern Rocky Mountains RUs). The following narratives describe dominant physical and biotic characteristics, patterns of owl distribution and habitat use, and the dominant patterns of land ownership and land use within each RU.

Colorado Plateau

The Colorado Plateau RU (Figure. II.B.3) coincides with the Colorado Plateau Physiographic Province (USGS 1970). It includes most of south-central and southern Utah plus portions of northern Arizona, northwestern New Mexico, and southwestern Colorado. Major landforms include interior basins and high plateaus dissected by deep canyons, including the canyons of the Colorado River and its tributaries (Williams 1986).

Grasslands and shrub-steppes dominate the Colorado Plateau at lower elevations, but woodlands and forests dominate the higher elevations (Bailey 1980, West 1983). Pinyon pine and various juniper species comprise the primary tree types in the woodland zone. A montane zone extends over areas on the high plateaus and mountains (Bailey 1980). Forest types in this zone include ponderosa pine, mixed-conifer, and spruce-fir. Conifers may extend to lower elevations in canyons. Deciduous woody species dominate riparian communities, and are most common along major streams.

The Mexican spotted owl reaches the northwestern limit of its range in this RU. Owl habitat appears to be naturally fragmented in this RU, with most owls found in disjunct canyon systems or on isolated mountain ranges. In southern Utah, breeding owls primarily inhabit deep, steep-walled canyons and hanging canyons. These canyons are typically surrounded by terrain that does not appear to support breeding spotted owls. Owls also apparently prefer canyon terrain in southwestern Colorado, particularly in and around Mesa Verde National Park. In northern Arizona and New Mexico, owls have been reported in both canyon and montane situations. Recent records of spotted owls exist for the Grand Canyon and Kaibab

Figure II.B.1. Recovery Units within the United States.

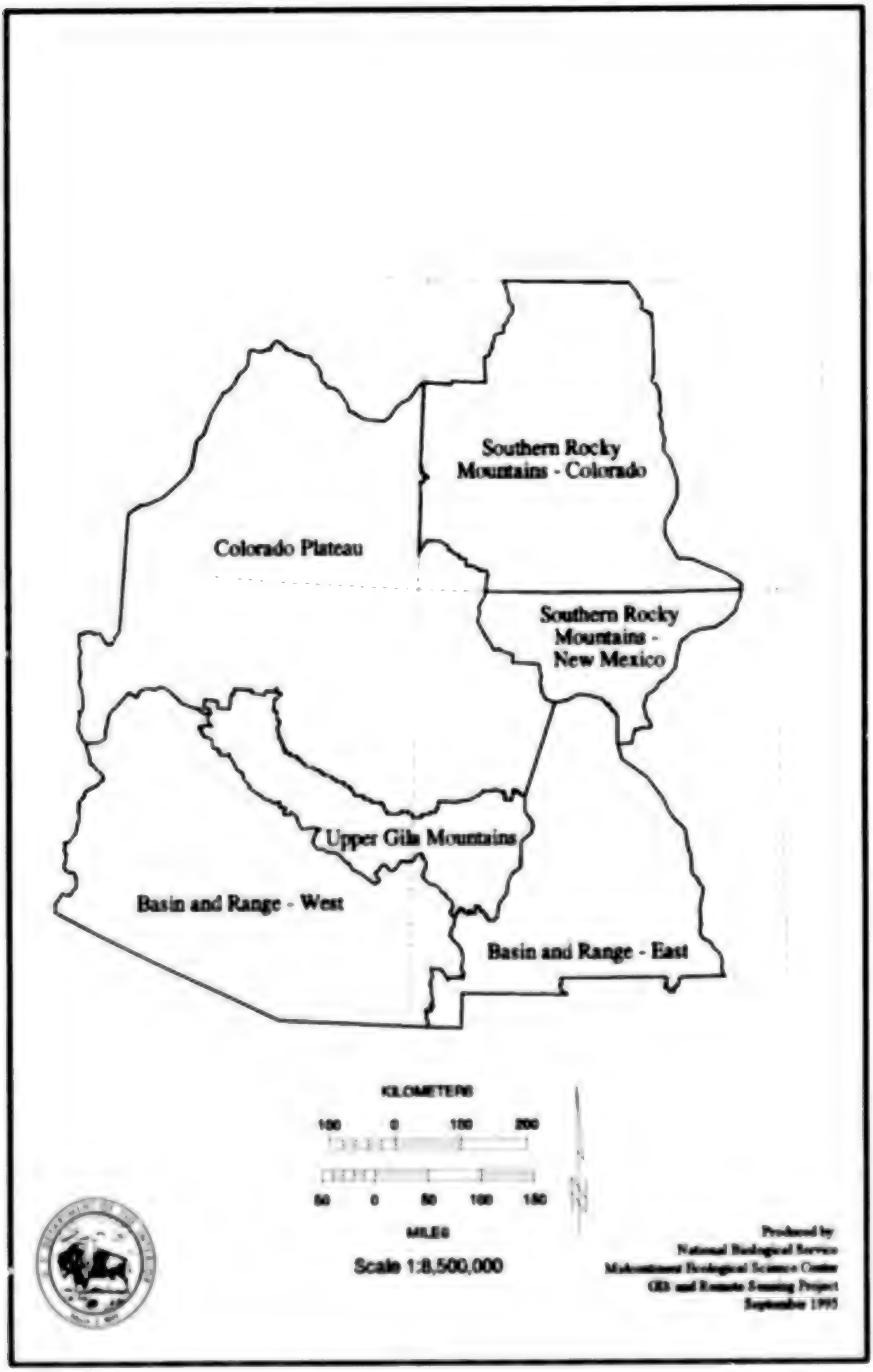

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Figure II.B.2. Recovery Units within the Republic of Mexico.

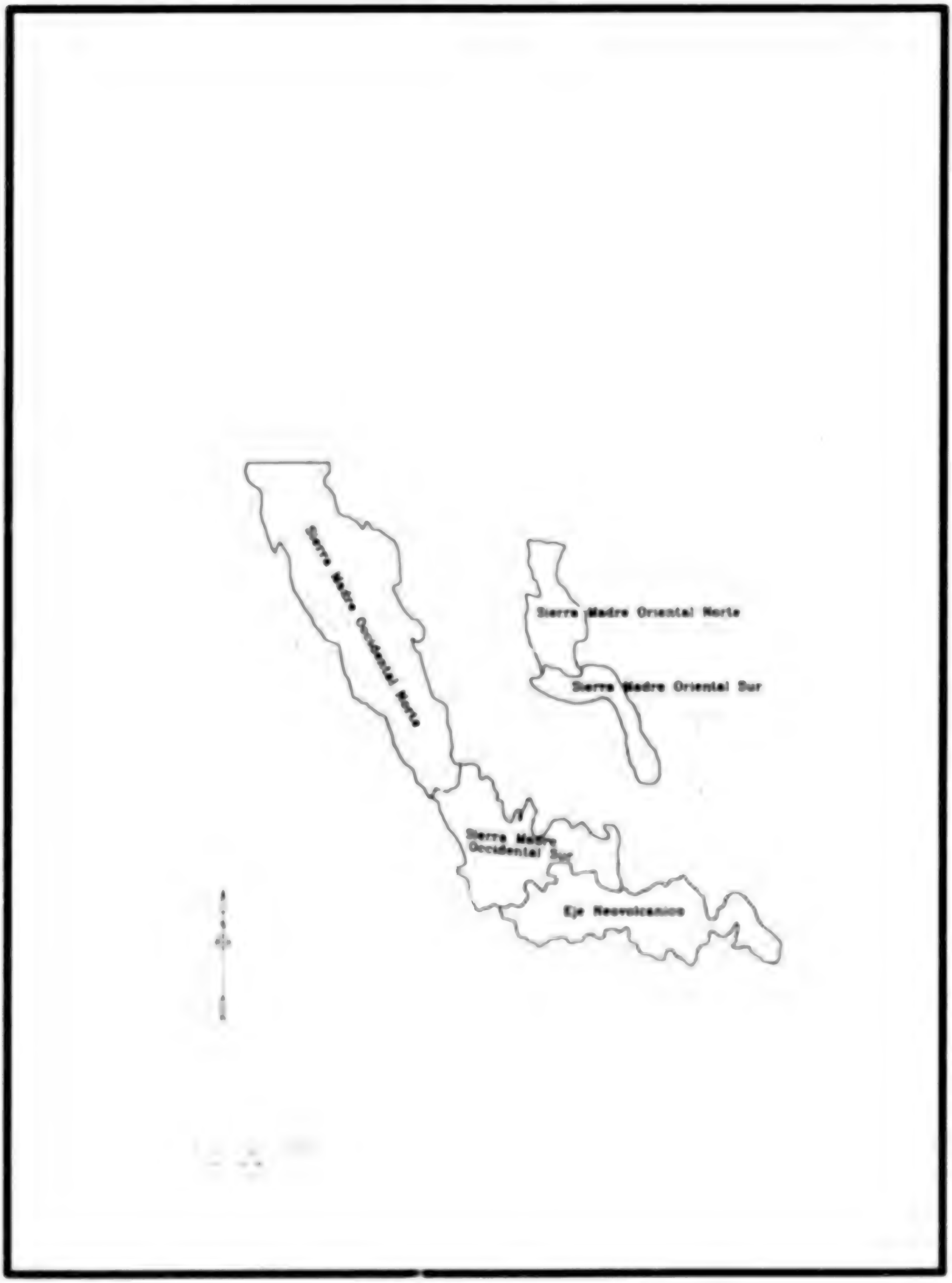
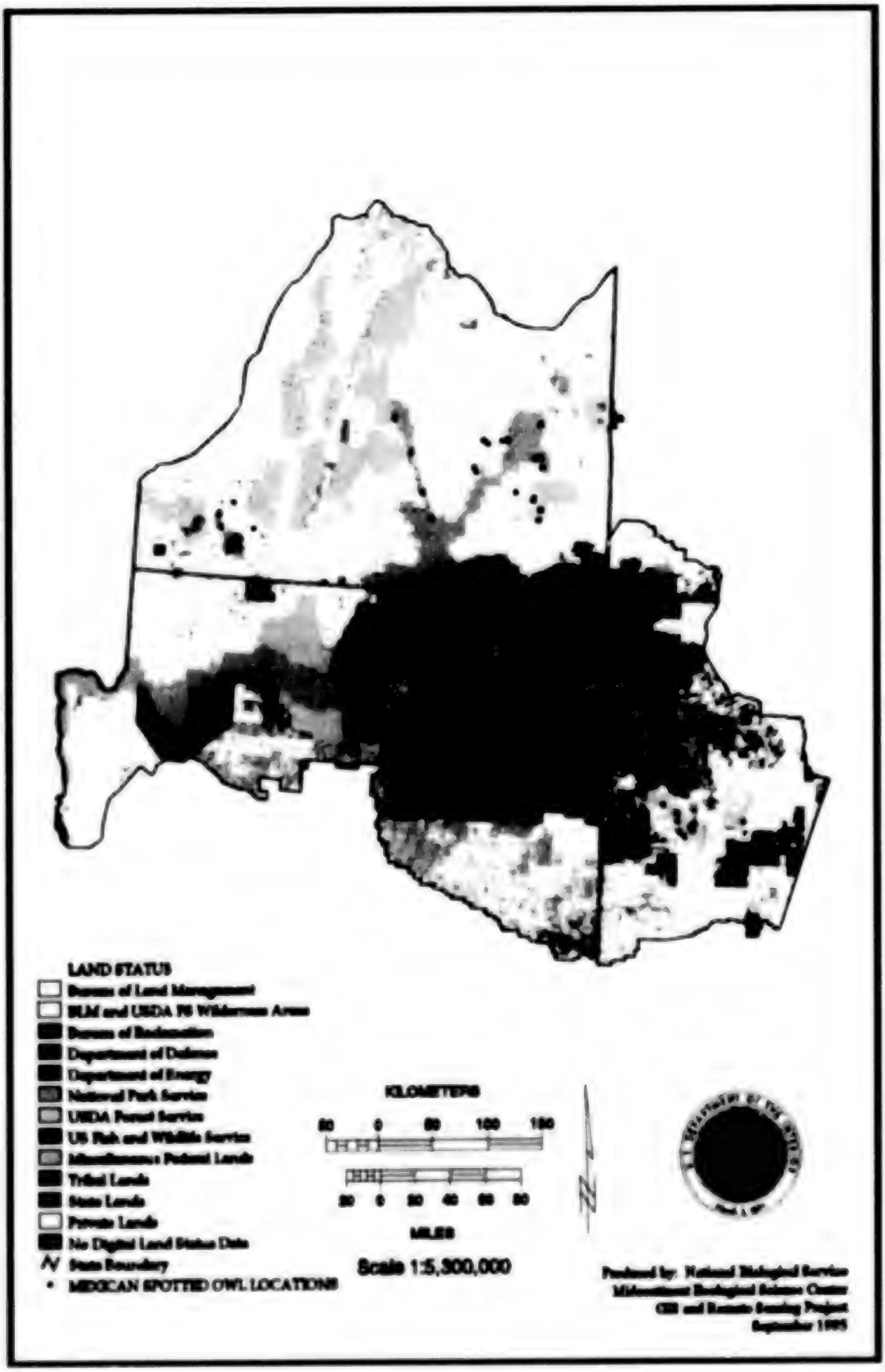

Sierra Madre Occidental Norte
Sierra Madre Oriental Norte
Sierra Madre Oriental Sur
Sierra Madre Occidental Sur
Eje Neovolcanico

Figure II.B.3. Colorado Plateau Recovery Unit.


LAND STATUS
Bureau of Land Management
BLM and USDA FS Wilderness Areas
Bureau of Reclamation
Department of Defense
Department of Energy
National Park Service
USDA Forest Service
US Fish and Wildlife Service
Miscellaneous Federal Lands
Tribal Lands
State Lands
Private Lands
No Digital Land Status Data
State Boundary
MEXICAN SPOTTED OWL LOCATIONS
KILOMETERS
50 0 50 100 150
20 0 20 40 60 80
MILES
Scale 1:5,300,000
Produced by: National Biological Service
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Plateau in Arizona, as well as for the Chuska Mountains, Black Mesa, Fort Defiance Plateau, and the Rainbow/Skeleton Plateau on the Navajo Reservation. In addition, records exist for the Zuni Mountains and Mount Taylor in New Mexico.

Federal lands account for 44% of this RU (Table II.B.1). Tribal lands collectively total 30%, with the largest single entity being the Navajo Reservation. Private ownership accounts for 19%, and State lands just 8%. Most Mexican spotted owls have been located on NPS lands in this RU, followed by FS and then BLM lands (Ward et al. 1995).

Recreation ranks first among land uses in National Parks within this RU. Activities such as hiking, camping, hunting, rock climbing, and mountain biking occur in owl habitat. Many of these activities plus off-road vehicle recreation also occur on BLM and FS lands throughout the Colorado Plateau. Various commercial enterprises relevant to industry and agriculture take place on these lands. Particularly important are livestock grazing, timber cutting, coal and uranium mining, oil and natural gas pumping, and continued exploration for these and other resources. Access roads, drill pads, pipelines, and loading and storage areas accompany all of these activities.

Southern Rocky Mountains - Colorado

This RU (Figure. II.B.4) falls partly within the Southern Rocky Mountains Physiographic Province (USGS 1970) and partly within the Colorado Plateau Ecoregion (Bailey 1980). The Colorado - New Mexico state line delimits the southern boundary of this RU because land-use practices and potential threats on Federal lands differ between these states. High mountain ranges characterize the RU (Curtis 1960); dominant ranges include the San Juan Mountains of southwestern Colorado, the Sangre de Cristo Mountains, and the Front Range.

Vegetation ranges from grasslands at low elevations through pinyon-juniper woodlands, interior shrublands, ponderosa pine, mixed-conifer and spruce-fir forests, to alpine tundra on the highest peaks (Daubenmire 1943).

The Mexican spotted owl reaches the northeastern limit of its range in this RU. Found primarily in canyons in this RU, the owls appear to occupy two disparate canyon habitat types. The first is sheer, slick-rock canyons containing widely scattered patches (up to 1 ha in size) of mature Douglas-fir in or near canyon bottoms or high on the canyon walls in short, hanging canyons. The second consists of steep canyons containing exposed bedrock cliffs either close to the canyon floor or, more typically, several tiers of exposed rock at various heights on the canyon walls (Reynolds 1993). Mature Douglas-fir, white fir, and ponderosa pine dominate canyon bottoms and both north- and east-facing slopes. Ponderosa pine grows on the more xeric south- and west-facing slopes, with pinyon-juniper growing on the mesa tops.

Federal lands encompass 55% of the RU, with the majority administered by the FS, followed by the BLM and NPS (Table II.B.1). Approximately 40% of the land is privately owned, 3% is State administrated, and <1% is Tribal land. Owls have been located on FS, BLM, NPS, and Tribal lands (Ward et al. 1995).

Land-use practices throughout the RU include timber cutting, grazing, mining, oil and natural gas pumping, plus all the associated facilities development such as access roads, pipelines, and staging and storage areas. Recreational activities include downhill and cross-country skiing, off-road driving, rock climbing, backpacking, camping, hiking, and mountain biking. Road, water, and urban development may also affect spotted owl habitat in this RU.

Southern Rocky Mountains - New Mexico

This RU (Figure. II.B.5) coincides with the Southern Rocky Mountains Physiographic Province (USGS 1970) and the Rocky Mountain Forest Province (Bailey 1980). The landscape includes a system of high ranges separated by deep structural basins of the northern Rio Grande rift (Williams 1986). Major ranges include the Sangre de Cristo and Jemez Mountains.

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Table II.B.1. Land ownership patterns (thousands of hectares) in Recovery Units (RU) within the United States.

LAND STATUS	CP[1]	SRM-CO[2]	SRM-NM[3]	UGM[4]	BR-W[5]	BR-E[6]
Federal Lands						
FS	2,503	5,546	1,220	3,520	2,238	495
BLM	7,672	2,227	520	145	3,359	1,829
NPS	1,678	140	14	17	172	59
Total Federal	**11,853**	**7,913**	**1,754**	**3,682**	**5,769**	**2,383**
State Lands						
AZ	957	0	0	20	2,905	0
NM	300	0	200	192	84	856
UT	862	0	0	0	0	0
CO	11	454	0	0	0	0
Total State	**2,129**	**454**	**200**	**212**	**2,989**	**856**
Tribal Lands	8,026	85	463	941	1,922	382
Private Lands	5,013	5,717	2,141	3,520	3,712	2,586
Other Lands	16	105	24	70	1,759	1,101
TOTAL	**27,037**	**14,274**	**4,582**	**8,425**	**16,151**	**7,308**

[1] Colorado Plateau RU
[2] Southern Rocky Mountain - Colorado RU
[3] Southern Rocky Mountain - New Mexico RU
[4] Upper Gila Mountains RU
[5] Basin and Range - West RU
[6] Basin and Range - East RU
[7] Other Lands include U.S. Department of Defense, Bureau of Reclamation, U.S. Fish and Wildlife Service Refuge Lands, etc.

Figure II.B.4. Southern Rocky Mountains - Colorado Recovery Unit.

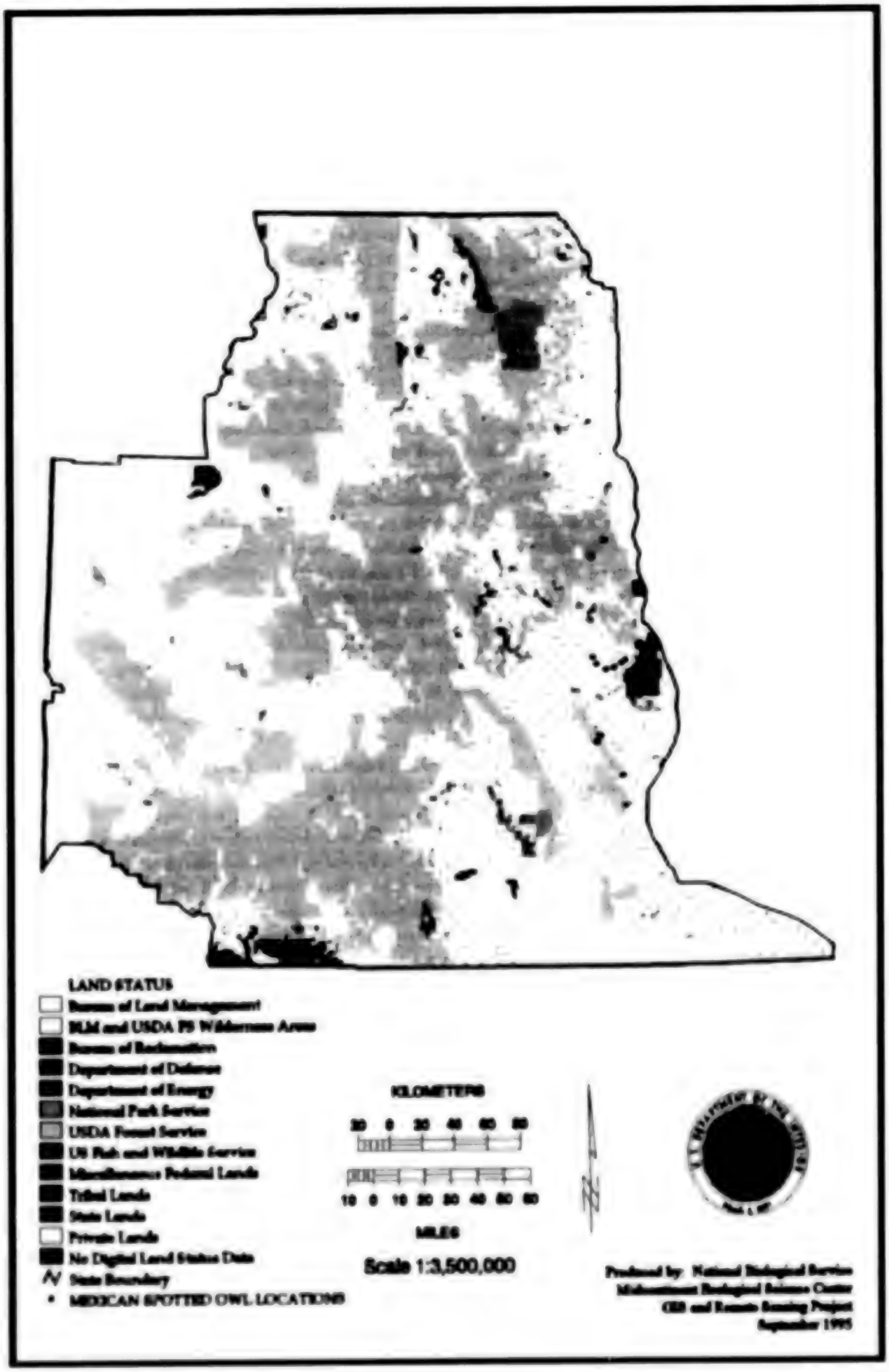
LAND STATUS
Bureau of Land Management
BLM and USDA FS Wilderness Areas
Bureau of Reclamation
Department of Defense
Department of Energy
National Park Service
USDA Forest Service
US Fish and Wildlife Service
Miscellaneous Federal Lands
Tribal Lands
State Lands
Private Lands
No Digital Land Status Data
State Boundary
MEXICAN SPOTTED OWL LOCATIONS
KILOMETERS
20 0 20 40 60 80
10 0 10 20 30 40 50 60
MILES
Scale 1:3,500,000
Produced by: National Biological Service
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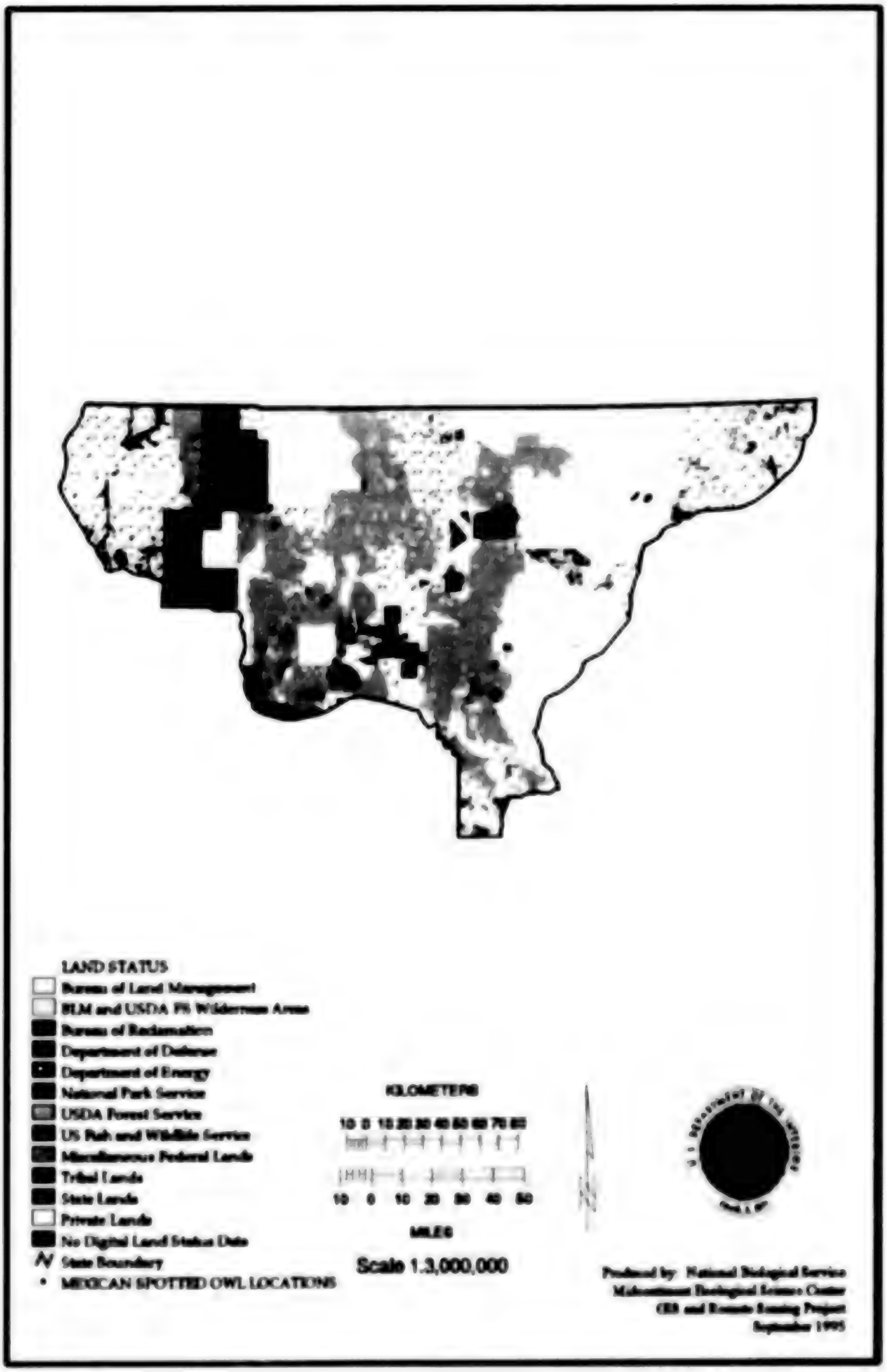
Figure II.B.5. Southern Rocky Mountains - New Mexico Recovery Unit.


LAND STATUS
Bureau of Land Management
BLM and USDA FS Wilderness Areas
Bureau of Reclamation
Department of Defense
Department of Energy
National Park Service
USDA Forest Service
US Fish and Wildlife Service
Miscellaneous Federal Lands
Tribal Lands
State Lands
Private Lands
No Digital Land Status Data
State Boundary
MEXICAN SPOTTED OWL LOCATIONS
KILOMETERS
10 0 10 20 30 40 50 60 70 80
10 0 10 20 30 40 50
MILES
Scale 1:3,000,000
Produced by: National Biological Service
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Vegetation within the unit has been modified by past logging, grazing, surface mining, fuelwood gathering, and fire suppression (Williams 1986, Van Hooser et al. 1993). Ponderosa pine, mixed-conifer, and spruce-fir forests are widespread at higher elevations. Juniper savanna and montane grasslands dominate lower elevations (Brown et al. 1980). In some areas mesa tops dominated by ponderosa pine and juniper are dissected by steep canyons. Vegetation on canyon slopes and bottoms includes a variety of coniferous and deciduous trees.

In general, owls inhabit steep terrain and canyons in this RU. They typically occur in mixed-conifer forests on steep slopes in the Sangre de Cristo Mountains, and in the Jemez Mountains they occupy canyons incised into volcanic rock. Patches of mixed-conifer forest which appear to contain attributes of owl habitat exist throughout northern New Mexico.

Privately owned lands comprise 47% of the total land within this RU (Table II.B.1). Federal lands account for 38%, numerous Pueblos and Tribal lands 10%, and State-administered lands 4%. Mexican spotted owls have been found primarily on FS lands, with several records in Bandelier National Monument as well (Johnson and Johnson 1985:5).

Dominant land-use practices within this RU include timber cutting and livestock grazing. Products such as vigas (small- to medium-diameter trees, generally 30-35cm dbh, used for traditional southwest ceiling beams), latillas (small-diameter trees, generally 10cm dbh aspen saplings, used for decorative southwest ceilings or fences), and fuelwood are harvested for personal use. Recreational activities in northern New Mexico include skiing, off-road driving, hiking, camping, and hunting. Other land uses include oil, natural gas, and mineral development, and pipeline corridors.

Upper Gila Mountains

The Upper Gila Mountains RU (Figure. II.B.6) is based on the Upper Gila Mountains Forest Province (Bailey 1980). Williams (1986) refers to this area as the Datil-Mogollon Section, part of a physiographic subdivision transitional between the Basin and Range and Colorado Plateau Provinces. This complex area consists of steep mountains and deep entrenched river drainages dissecting high plateaus. The Mogollon Rim, a prominent fault scarp, bisects the unit.

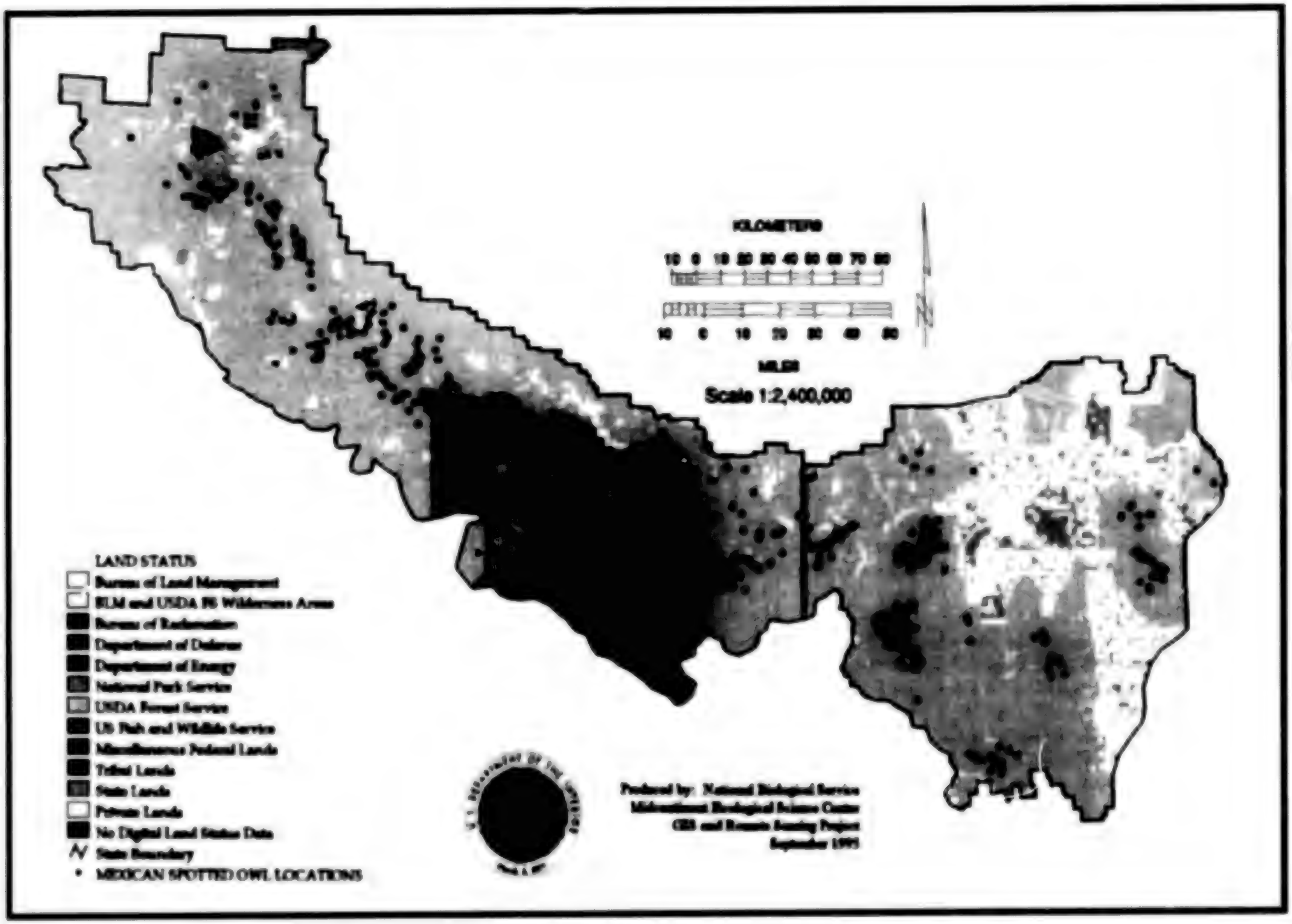
McLaughlin (1986) described a "Mogollon" floral element in this region. The vegetation is a zonal pattern of grasslands at lower elevations upward through pinyon-juniper woodlands, ponderosa pine, mixed-conifer, and spruce-fir forests at higher elevations. Many canyons contain stringers of deciduous riparian forests, particularly at low and middle elevations. This unit contains the largest contiguous ponderosa pine forest in North American, an unbroken band of forest 25 to 40 miles wide and approximately 300 miles long extending from north-central Arizona to west-central New Mexico (Cooper 1960).

Mexican spotted owls are widely distributed and use a variety of habitats within the Upper Gila Mountains RU. Owls are most common in mixed-conifer forests dominated by Douglas fir and/or white fir and canyons with varying degrees of forest cover (Ganey and Balda 1989a, Ganey and Dick 1995). Owls also occur in ponderosa pine-Gambel oak forest, where they are typically found in stands containing well-developed understories of Gambel oak.

Federal lands, mostly FS, encompass 44% of this RU (Table II.B.1). Tribal lands account for 11%, privately owned lands 42%, and State lands 3%. The greatest concentration of the known Mexican spotted owl population occurs within this RU, and most known owl locations occur on FS and Tribal lands (Ward et al. 1995). Many spotted owls are found within wilderness areas in this RU with the Gila Wilderness supporting the largest known wilderness population.

The major land use within this RU is timber harvest. All of the National Forests as well as the Fort Apache and San Carlos Indian Reservations have active timber management programs. Fuelwood harvest, including both personal and commercial harvest, occurs across much of this unit. Livestock grazing is ubiquitous on FS lands and widespread over large portions of the Fort Apache and San Carlos Indian Reservations. In

Figure II.B.6. Upper Gila Mountains Recovery Unit.


KILOMETERS
10 0 10 20 30 40 50 60 70 80
10 0 10 20 30 40 50
MILES
Scale 1:2,400,000
LAND STATUS
Bureau of Land Management
BLM and USDA FS Wilderness Areas
Bureau of Reclamation
Department of Defense
Department of Energy
National Park Service
USDA Forest Service
US Fish and Wildlife Service
Miscellaneous Federal Lands
Tribal Lands
State Lands
Private Lands
No Digital Land Status Data
State Boundary
MEXICAN SPOTTED OWL LOCATIONS
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addition, recreational activities such as hiking, camping, and hunting attract many people to this RU.

Basin and Range - West

The Basin and Range Area Province (USGS 1970, Bailey 1980) provided the basis for two RUs (Figure. II.B.7). We subdivided the Basin and Range area into eastern and western units using the Continental Divide as the partition between these units. The division was based on differences in climatic and floristic characteristics between these areas. The Basin and Range - West flora is dominated by Madrean elements while the Basin and Range - East unit shows more Rocky Mountain affinities (Brown et al. 1980).

Geologically, the Basin and Range - West RU exhibits horst and graben faulting (Wilson 1962) with numerous fault-block mountains separated by valleys. Complex faulting and canyon carving define the physical landscape within these mountains. These ranges include, but are not limited to, the Chiricahua, Huachuca, Pinaleno, Bradshaw, Pinal, Santa Catalina, Santa Rita, Patagonia, Santa Teresa, Atascosa, Mule, Dragoon, Peloncillo, Mazatzal, and Rincon Mountains.

Vegetation ranges from desert scrubland and semi-desert grassland in the valleys upwards to montane forests. Montane vegetation includes interior chaparral, encinal woodlands, and Madrean pine-oak woodlands at low and middle elevations, with ponderosa pine, mixed-conifer, and spruce-fir forests at higher elevations (Brown et al. 1980). Isolated mountain ranges are surrounded by Sonoran and Chihuahuan desert basins.

Mexican spotted owls occupy a wide range of habitat types within this RU. The majority of owls occur in isolated mountain ranges where they inhabit encinal oak woodlands, mixed-conifer and pine-oak forests, and rocky canyons (Ganey and Balda 1989a, Duncan and Taiz 1992, Ganey et al. 1992).

Federal lands encompass 36% of this RU, mostly administered by the BLM followed by the FS and a small portion by the NPS (Table II.B.1). Privately owned lands amount to 22%, State lands 19%, Tribal lands (San Carlos Apache Reservation) 12%, and DOD lands 11%. Within this RU the Mexican spotted owl occupies primarily FS lands, and the majority occur within the Coronado National Forest. DOD lands also support the owl on Fort Huachuca Army Base in the Huachuca Mountains.

Recreation dominates land use within this unit. Activities such as hiking, birdwatching, camping, off-road driving, skiing, and hunting are particularly popular. Livestock grazing is widespread but most intensive at low and middle elevations. Urban and rural development and mining modify portions of the Basin and Range - West landscape. Timber harvest occurs mainly on the Prescott National Forest and the San Carlos Apache Indian Reservation. According to the Coronado National Forest Land Management Plan, timber cutting is used sparingly to enhance wildlife and recreational values. Military training maneuvers take place in and around Mexican spotted owl habitat on Fort Huachuca Army Base.

Basin and Range - East

We delineated the Basin and Range - East RU (Figure. II.B.8) based on the Basin and Range Area Province (USGS 1970) and the Desert and Steppic Ecoregions (Bailey 1980). This RU is characterized by numerous parallel mountain ranges separated by alluvial valleys and broad, flat basins. Williams (1986) refers to the Rio Grande Rift as the separation between the Basin and Range physiographic province and the Colorado Plateau and Upper Gila Mountains physiographic provinces. The climate features mild winters, as indicated by the presence of broad-leaved evergreen plants at relatively high elevations (USDA 1991).

Regional vegetation ranges from Chihuahuan desert scrubland and Great Basin grasslands at low elevations, through Great Basin woodland (pinyon-juniper) at middle elevations to petran montane coniferous forests at high elevations (Brown et al. 1980). Montane habitat includes ponderosa pine, mixed-conifer, and spruce-fir forests and is patchily distributed throughout the higher mountain ranges. Cottonwood bosques as well as other riparian

Figure II.B.7. Basin and Range - West Recovery Unit.

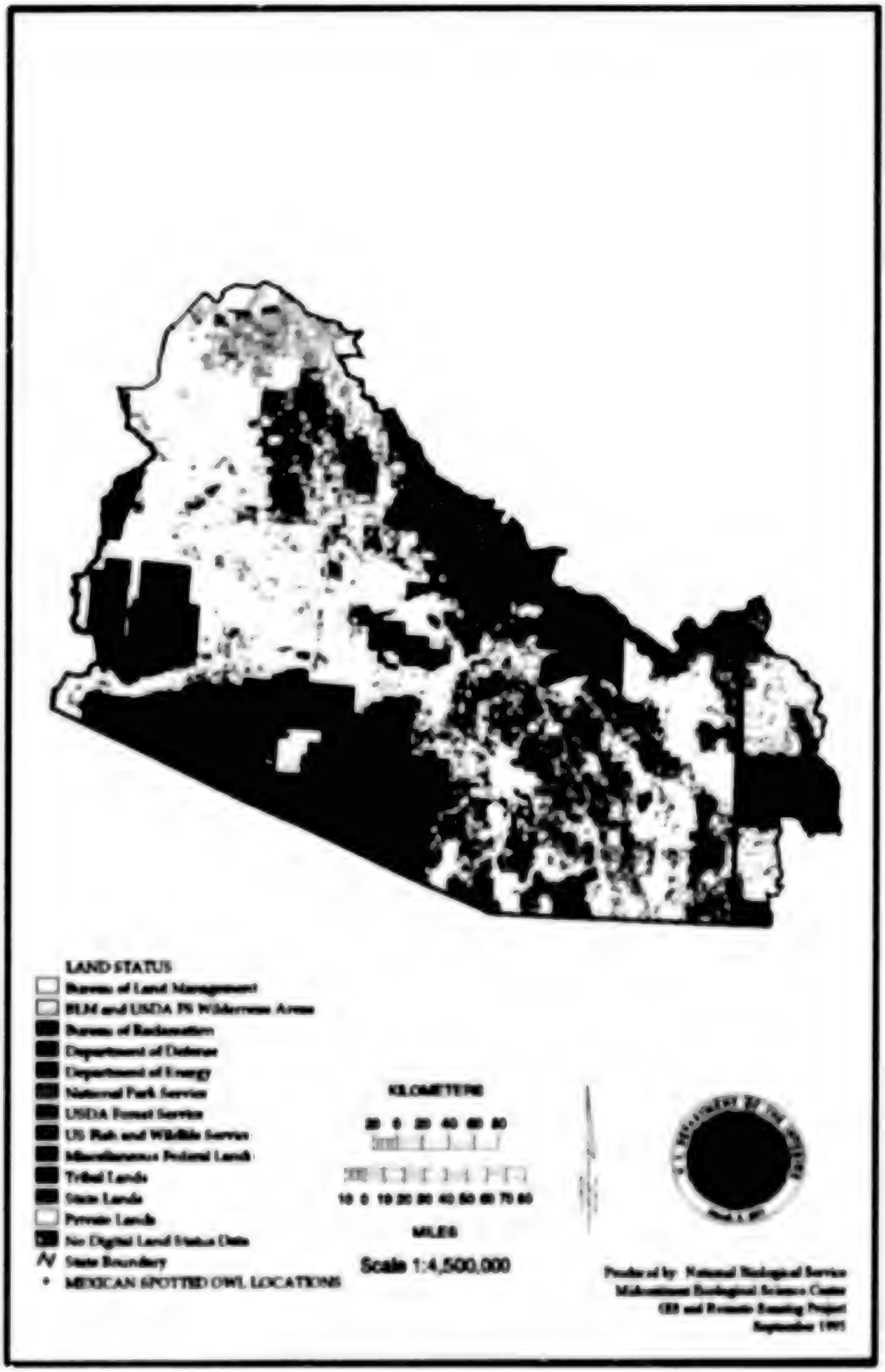
LAND STATUS
Bureau of Land Management
BLM and USDA FS Wilderness Areas
Bureau of Reclamation
Department of Defense
Department of Energy
National Park Service
USDA Forest Service
US Fish and Wildlife Service
Miscellaneous Federal Lands
Tribal Lands
State Lands
Private Lands
No Digital Land Status Data
State Boundary
MEXICAN SPOTTED OWL LOCATIONS
KILOMETERS
20 0 20 40 60 80
10 0 10 20 30 40 50 60 70 80
MILES
Scale 1:4,500,000
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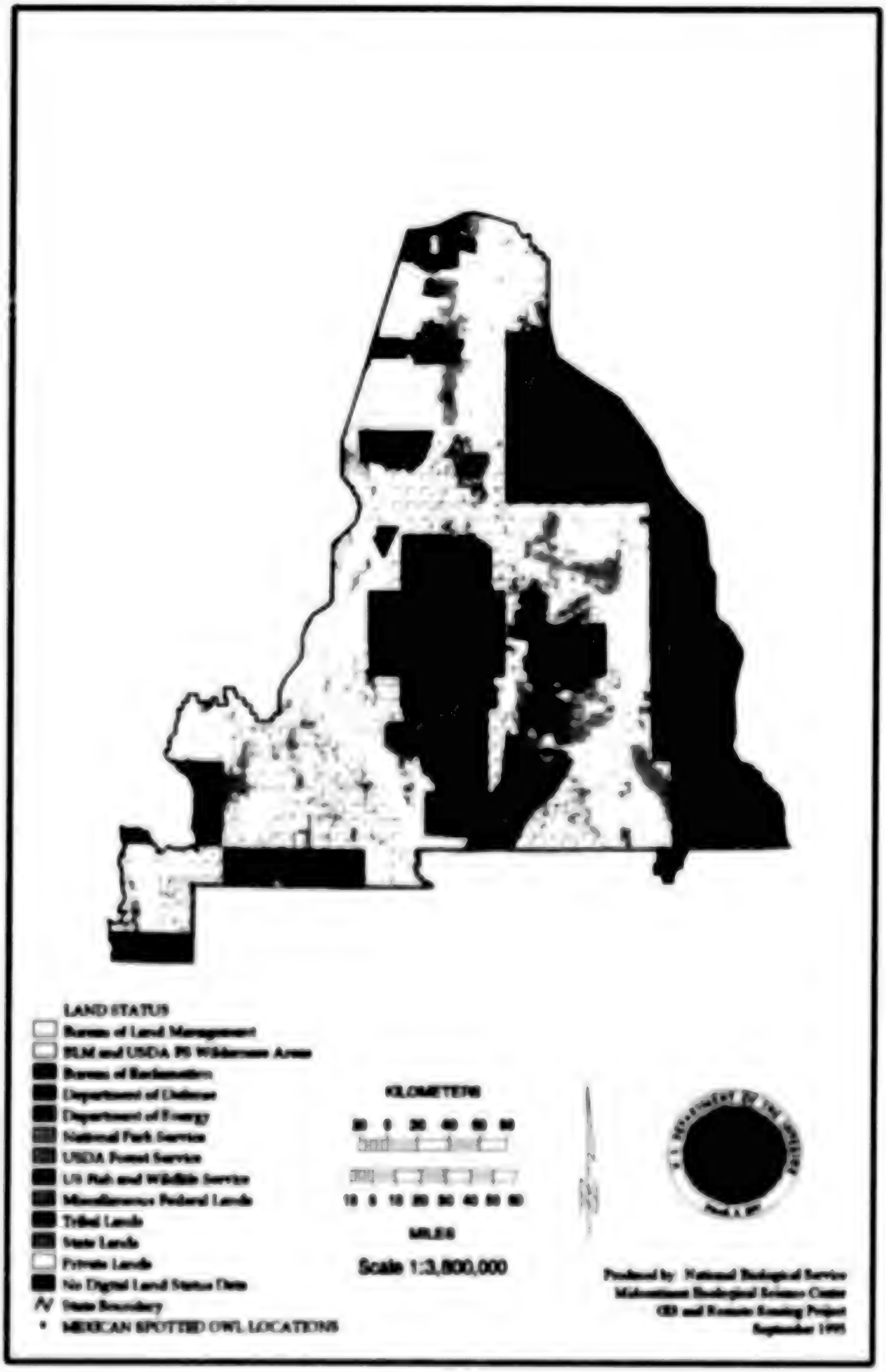
Figure II.B.8. Basin and Range - East Recovery Unit


LAND STATUS
Bureau of Land Management
BLM and USDA FS Wilderness Areas
Bureau of Reclamation
Department of Defense
Department of Energy
National Park Service
USDA Forest Service
US Fish and Wildlife Service
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KILOMETERS
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10 0 10 20 30 40 50 60
MILES
Scale 1:3,800,000
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vegetation exist along the Rio Grande corridor. Montane and especially riparian communities have been altered considerably by human activities.

Mexican spotted owls occur in the isolated mountain ranges scattered across this RU. They are most common in mixed-conifer forest but are also found in ponderosa pine forest and pinyon-juniper woodland (Skaggs and Raitt 1988). The owl has been found within mixed-conifer canyon habitat in the Guadalupe Mountains (McDonald et al. 1991).

Of the Basin and Range - East RU land area, private lands encompass 35%, Federal lands 48%, State lands 12%, and Tribal lands 5% (Table II.B.1). The Mescalero Apache Indian Reservation comprises the largest portion of the Tribal lands. The majority of known Mexican spotted owls are located on FS lands, with some found on NPS and Tribal lands.

Dominant land uses within this RU include timber management and livestock grazing. Recreational activities such as off-road driving, skiing, hiking, camping, and hunting are also locally common within the RU.

MEXICO

Conserving its natural resources has been a significant challenge for Mexico. To meet the challenge, the National System of Protected Areas was formed; in March of 1988, the General Law of Ecological Balance and Environmental Protection was implemented. A total of 5,992 km^2 (almost 600,000 ha) has been decreed as Protected Natural Areas within the RUs. This expanse has been classified into nine categories according to the management objectives and the legal uses of particular areas. The categories include: (1) Biosphere Reserves, (2) Special Biosphere Reserves, (3) National Parks, (4) National Monuments, (5) National Marine Parks, (6) Areas of Protection of Natural Resources, (7) Areas of Protection of Land and Aquatic Wildlife, (8) Urban Parks, and (9) Areas Subject to Ecological Conservation. Overall, there are three types of land tenancy exist in Mexico: (1) Federal lands, which include different institutions of the Federal Government such as Protected Natural Areas; (2) ejidal land, which includes land allotted by the Mexican Government to a person or community, for agriculture, forestry, mining, or other uses; and (3) private land.

The five RUs in Mexico include Sierra Madre Occidental - Norte, Sierra Madre Oriental - Norte, Sierra Madre Occidental -Sur, Sierra Madre Oriental - Sur, and Eje Neovolcanico (Figure. II.B.2). Three major physiographic provinces were used in the delineation: Sierra Madre Occidental, Sierra Madre Oriental, and Sistema Volcanico Transversal (Cuanalo et al. 1989). Criteria used to delineate RUs in Mexico were similar to that used to conform the RUs in the United States. These criteria, listed in order of importance, were: (1) distribution of the spotted owl, (2) local vegetation, (3) physiographic features, (4) administrative boundaries, and (5) potential threats to the conservation of the owl and its habitat.

Owl distribution is disjunct across Mexico. Williams and Skaggs (1993) report spotted owls at 53 locations in 11 mainland Mexican States. Although vegetation types differ throughout each RU, oak and pine-oak forest types appeared to be commonly associated with owl habitat in most or all RUs. These oak species included *Quercus resinosa, Q. gentryi, Q. eduardii, Q. grisea, Q. chihuahuensis, Q. potosina/Q. laeta, and Q. coccolobifolia*. Further, *Pinus teocote* was the most common pine occurring on upper mesas and occasionally on north-facing slopes in some areas where owls were found. Land uses within all RUs include timber cutting, cattle and sheep grazing, fuelwood gathering, and clearing forested areas for agriculture. Although, these land uses are practiced in different amounts throughout each RU, the majority occur within ejidos. The following narratives describe dominant physical and biotic attributes, distribution of owls, and land administration and ownership of each unit.

Sierra Madre Occidental - Norte

Covering an enormous area, the Sierra Madre Occidental - Norte includes parts of the States of Chihuahua, Sinaloa, Durango, and Sonora. In general, this area is characterized by isolated mountain ranges surrounded by both narrow and wide valleys. Vegetation communities consist of pine-oak forest, tropical deciduous forest, oak forest, microphyll shrub, and grassland.

Mexican spotted owls have been reported in the northern and western portions of this RU. A recent study in Sonora found 12 sites in isolated mountain ranges (Cirett-Galan and Diaz 1993). The owls occupied canyons and slopes with various exposures, and most were found in pine-oak forest. In portions of Chihuahua, 25 owls were located at 13 different localities in several mountain ranges (Tarango et al. 1994). Most owls were found in small, isolated patches of pine-oak forest in canyons.

Records for the State of Sinaloa are limited. There are at least two records from the high Rancho Liebre Barranca, near the Sinaloa-Durango State line (Williams and Skaggs 1993). These sites were described as deep canyons containing pine-oak and subtropical vegetation (Alden 1969).

Private lands comprise 74%, ejidos 25%, and Federal lands 1% of the total land within this RU (Table II.B.2). Chihuahua has two National Parks: Cascadas de Bassaseachic, and Cumbres de Majalca. This RU also includes La Michilia Biosphere Reserve, located in Durango. Biosphere Reserves are protected areas with relatively unaltered landscapes and contain endemic, threatened, or endangered species.

Sierra Madre Oriental - Norte

The Sierra Madre Oriental - Norte includes the central portion of the State of Coahuila. This area is characterized by broad mountain ranges surrounded by valleys. Vegetation consists of grasslands, mesquite woodland, dwarf oak groves, submontane shrubland, desert shrubland, crasicaule shrub, and pine-oak and oak forests.

Two owl records are reported for this RU. At one of these sites an owl was observed roosting in a canyon bottom under a dense canopy of maples and oaks. Vegetation in the other canyon was described as "garden-like," containing pines, oaks, and madrones (Williams and Skaggs 1993).

Lands in this RU are almost entirely privately owned (Table II.B.2). Private lands encompass over 99% and ejidos comprise < 1% of the total land area. No Protected Natural Areas of any category exist in this RU.

Sierra Madre Occidental - Sur

The Sierra Madre Occidental - Sur RU includes parts of the States of Durango, Zacatecas, San Luis Potosi, Aguascalientes, Jalisco, Nayarit, Queretaro, and Guanajuato. In general, this area is characterized by isolated

Table II.B.2. Land ownership patterns (thousands of hectares) in Recovery Units within Mexico.

Land Ownership	**SMOcN**[1]	**SMOrN**[2]	**SMOcS**[3]	**SMOrS**[4]	**ENV**[5]
Ejidos[6]	4,783	28	1,220	235	441
PNAs[7]	46	0	38	250	274
Private	14,100	7,506	2,075	1,630	5,306
Total	**18,929**	**7,534**	**3,333**	**2,115**	**6,021**

[1] Sierra Madre Occidental - Norte RU

[2] Sierra Madre Oriental - Norte RU

[3] Sierra Madre Occidental - Sur RU

[4] Sierra Madre Oriental - Sur RU

[5] Eje Neovolcanico RU

[6] Ejidos are lands allocated by the Mexican Government to a person or community, to be used for agriculture, forestry, mining, etc.

[7] Protected Natural Areas

mountains, valleys, and severely dissected canyons and gorges. Vegetation includes mesquite woodland, submontane shrub, grasslands, pine-oak forest, crasicaule shrub, low tropical deciduous forest, and desert shrubland.

Records exist for owls in La Michilia Biosphere Reserve. In addition, Mexican spotted owls have recently been found in Aguascalientes near the border of Zacatecas, in the Sierra Fria (Williams and Skaggs 1993). Owl records also exist within Guanajuato State.

Private lands comprise 62%, ejidos 37%, and Federal lands 1% of this RU (Table II.B.2). Federal lands include two National Parks: El Climatario in Queretaro State, and Gogorton in the State of San Luis Potosi. In addition, this RU includes Mariposa Monarca Sanctuary, a Special Biosphere Reserve. The Special Biosphere Reserves have one or more ecosystems, are relatively unaltered by anthropogenic activities, and contain endemic, threatened, or endangered species.

Sierra Madre Oriental - Sur

The Sierra Madre Oriental - Sur includes parts of the States of Coahuila, Nuevo Leon, and Tamaulipas. This RU is characterized by long ridges with sharp pinnacles, narrow valleys, and a few plateaus. Vegetation consists of pine forest, submontane shrublands, dwarf oak, and desert rosetofilo shrublands.

Mexican spotted owls have been found in the southern portions of Coahuila (Williams and Skaggs 1993) and in Tamaulipas (Ward et al. 1995). The owls were found in oak, pine, juniper, and mixed-conifer forests. They were reported to use cliff sites for nesting and roosting.

Five locations have been reported in Nuevo Leon. These sites were described as pine-oak and mixed-conifer forests with large cliffs having northeast exposures.

This RU is comprised of 77% private property, 12% Federal lands, and 11% ejidos (Table II.B.2). The Federal lands include one National Park, Cumbres de Monterrey in Nuevo Leon. Natural Monument Cerro de la Silla, in Nuevo Leon, is also within this RU. Natural Monuments possess one or more elements of national significance. These elements may be sites or natural objects that have been placed under absolute protection because of their unique and exceptional makeup, aesthetic interest, and/or historical or scientific value.

Eje Neovolvanico

The Eje Neovolcanico RU covers portions of many States including Jalisco, Michoacan, Guanajuato, Queretaro, Hidalgo, Mexico, Guerrero, Puebla, Morelaos, Tlaxcala Veracruz, and Oaxaca. This RU is characterized by volcanic cones severely dissected by ravines. The area also includes rounded hills, slopes, and plateaus. Vegetation communities include pine-oak forest, grassland, low tropical deciduous forest, crasicaule shrub, oak forest, juniper forest, pine forest, mesquite woodlands, and desert shrublands.

Mexican spotted owls have been reported in Jalisco on the volcano of Cerro Nevado de Colima (Voacan de Nieve). Vegetation in this area consists of pine-oak forest. One Mexican spotted owl was collected near the city of Uruapan in the State of Michoacan at Cerro de Tancitaro. However, this area is now urbanized and no longer contains owl habitat. Although other states in this RU appear to contain suitable owl habitat, Jalisco is the only State known to have recent records of spotted owls.

This unit is comprised of 88% private lands, 5% Federal lands, and 7% ejidos (Table II.B.2). This RU includes 19 National Parks, 1 Special Biosphere Reserve, and 1 Area of Protection of Land and Aquatic Wildlife.

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C. DEFINITIONS OF FOREST COVER TYPES

James L. Dick, Jr., Joseph L. Ganey, and William H. Moir

This Recovery Plan proposes specific guidelines for several forest cover types, including mixed-conifer, pine-oak, and riparian forests (III.B). This is based on: (1) considerable evidence that these cover types are of specific importance to the Mexican spotted owl in terms of providing habitat for nesting, roosting, and foraging activities (Ganey and Dick 1995); and (2) the Team's desire to target guidelines for the most appropriate habitats and avoid imposing restrictions where specific guidelines to protect spotted owl habitat are unwarranted.

Numerous treatments deal with the concepts of classifying vegetation to cover or habitat types (e.g., Daubenmire 1952, 1968, Pfister 1989). These concepts will not be reviewed in any depth here. In general, we accept the view that the basic unit of classification of climax vegetation is the plant association (Küchler 1964, Daubenmire 1968, Pfister 1989). These associations are defined using information on present species composition and successional pathways. The problem with applying guidelines to plant associations is that many forests in the southwest may and should not be in or even near a climax condition because of the frequency and intensity of disturbance events in these forests. For example, in an analysis of Mexican spotted owl habitat on the Alpine Ranger District, Apache-Sitgreaves National Forest, the Team determined that habitat classifications based on current and climax vegetation gave very different results. Based on current vegetation, important roosting and nesting habitat typed out as mixed-conifer forest, whereas a classification based on potential natural vegetation (PNV) typed many of these areas as spruce-fir forest. This points out the need for clear, operational definitions of cover types to be used when applying guidelines under this Plan.

In this section, we first review some of the relevant literature on forest cover types in the southwest, and then provide operational definitions and a simple key that should allow land managers to classify lands in a manner compatible with the recommendations provided in this Plan. Our intent is not to provide a comprehensive classification scheme here or to supplant extant classification schemes. Rather, our intent is to provide guidance to land managers charged with applying Recovery Plan guidelines and to facilitate uniform application of guidelines across administrative boundaries.

LITERATURE REVIEW

Extensive literature exists on both vegetation classification in general and on classification systems for southwestern forests. Our intent is not to review that literature exhaustively, but to present an overview of some classification systems currently in use. This information will provide the background for discussion of forest type definitions relevant to this Plan.

Soil temperature (STR) and moisture (SMR) regimes provide one possible approach to classifying forest types. STR and SMR may be used to conceptualize three major groups of cover types in the southwestern United States. Ponderosa pine forests typically occur where the STR is frigid or (in southern Arizona and southwestern New Mexico) mesic and where the SMR is ustic. Spruce-fir forests everywhere occur on soils of cryic SMR, whereas mixed-conifer forests are uniquely udic and frigid in their SMR and STR, respectively. The implication is that these soil parameters partition the soil environment into three mutually exclusive but all encompassing classes (USDA 1991). These classes are generally consistent with the three major forest type groups mentioned.

Most vegetation-classification schemes, however, are based on either exisiting vegetation or on a combination of existing vegetation and knowledge of successional potential (Layser and Schubert 1979). Eyre (1980) discussed the practice of defining forest cover types on the basis of "present occupancy of an area by tree species." He further described the practice of naming forest types after the dominant tree species. Dominance was determined by relative proportions of basal area, and the type name was usually confined to one or two species. An added requirement was that a species must contribute at least 20% of the total basal area to be used in the type name.

Numerous authors have expanded on this approach, and developed and refined classification systems for southwestern forests based not only on existing vegetation but also on estimated site potential. These treatments are discussed below.

Ponderosa Pine

The ponderosa pine forest type occurs in what Moir (1993) described as the Lower Montane Coniferous Forest. Forests in this zone are dominated by pines, sometimes co-occurring with junipers and oaks. The climate is sometimes borderline for forests, with moisture becoming limiting in the upper portions of the soil profile during part of the long growing season. Moir (1993) included the following series in this general forest type: Ponderosa pine - Gambel oak, Ponderosa pine - silverleaf oak, Ponderosa pine - pinyon pine - Gambel oak, Ponderosa pine - pinyon pine - gray oak, and Chihuahua pine.

Layser and Schubert (1979) described the Ponderosa Pine Series as being generally dominated by the Rocky Mountain variety of ponderosa pine (var. *scopulorum*), except in southeastern Arizona, where *Pinus ponderosa* var. *arizonica* dominates. This series occurs in areas that are generally too warm or too dry for Douglas-fir and/or true firs. Gambel oak is often a long-lived seral species. The Ponderosa Pine Series in the southwest is generally more complex than that described for the northern Rocky Mountains, because of the additional associated tree species and the presence of two varieties of ponderosa pine (Layser and Schubert 1979). Hanks et al. (1983), Alexander et al. (1984a), Alexander and Ronco (1987), DeVelice et al. (1986), and Fitzhugh et al. (1987) provide further discussion of the Ponderosa Pine Series and associated habitat types and phases in the southwestern United States.

Mixed-Conifer

Mixed-conifer forests in the southwestern United States generally approximate to the Upper Montane Coniferous Forest discussed by Moir (1993). Mixed-conifer forests are most common between approximately 2,440 and 3,050 m (8,000-10,000 feet) in elevation, but may occur higher or lower depending on topography and aspect. In particular, mixed-conifer forest may extend to lower elevations in canyon systems and cold-air drainages.

Southwestern mixed-conifer forests are among the most complex forest types known, exhibiting great variation in tree composition (USDA 1983). Overstory species in these forests include Rocky Mountain Douglas-fir, white fir, Rocky Mountain ponderosa pine, quaking aspen, southwestern white pine, limber pine, and blue spruce. Forests in any successional stage may be mixed-conifer if tree regeneration indicates any of the above tree species will assume dominance in time. Some stands may consist of only two species, whereas others may contain as many as eight associates (USDA 1983). Gambel oak and/or silverleaf oak may share overstory or understory dominance with the conifers in mixed-conifer forests. Again, one of the key attributes of southwestern mixed-conifer is its inherent variability and diversity.

At the warm/dry end of the environmental continuum, mixed-conifer forest typically intergrades with ponderosa pine forest. Where Douglas-fir, white fir, or blue spruce, either singly or in combination, constitute less than 5% cover or are considered "accidental" in late successional stands, these stands are not included in the mixed-conifer forest classification.

At the cold/wet end of the environmental continuum, mixed-conifer forest typically intergrades with subalpine spruce-fir forest. Where corkbark fir *(Abies lasiocarpa* var. *arizonica)*, subalpine fir *(A. lasiocarpa* var. *lasiocarpa)*, or Englemann spruce, either singly or in common, constitute more than 5% of the cover or are not considered "accidental," the forest is subalpine and no longer considered mixed-conifer.

In addition to this general description, numerous authors have discussed aspects of southwestern mixed-conifer forests or classification of southwestern forests. Pearson (1931) described a "Douglas-fir Zone." He stated that although Douglas-fir is generally regarded as the characteristic tree of this type, it rarely occurs in pure stands. Instead, it commonly occurs in stands with white fir, limber or Mexican white pine, and blue spruce. Western yellow pine (e.g., ponderosa pine) is common in the lower portion of the type, and Engelmann spruce is common in the upper portion. Quaking aspen is common throughout the type.

Choate (1966) also described Douglas-fir forests in New Mexico as seldom growing in pure stands. He also stated that it mixes with ponderosa pine at lower elevations and with true firs and spruce at the upper limits. White fir and quaking aspen are common associates throughout the Douglas-fir type.

USDA (1992) described old-growth attributes by cover types, including a "mixed-species group" Forest Cover Type, which included the Douglas-fir, white fir, blue spruce, and limber pine forest cover types. They described these mixed-species stands as having a rich diversity of vegetation, typically including at least three tree species.

Moir (1993) described mixed-conifer forests as upper montane coniferous forests featuring Douglas-fir, white fir, several tall pine species, blue spruce, and quaking aspen. He included the following series in this general forest type: Blue Spruce, White fir - Douglas-fir, Douglas-fir - Southwestern White Pine, White Fir - Douglas-fir - Ponderosa Pine, Douglas-fir - Limber Pine - Bristlecone Pine, Douglas-fir - Gambel Oak, and Douglas-fir - Silverleaf Oak. These forests are very productive because of ample precipitation and soils that are well watered throughout the long growing season.

Fletcher and Hollis (1994) described mixed conifer forest cover types as those dominated by Douglas-fir and/or white fir, usually containing varying amounts of ponderosa pine, southwestern white pine, and/or limber pine. Hardwood species, including rocky mountain maple *(Acer glabrum)*, boxelder *(A. negundo)*, bigtooth maple *(A. grandidentatum)*, Gambel oak, quaking aspen, and other hardwood species may also be present. Douglas-fir and/or white fir typically comprise at least 40 percent and hardwood species less than 40 percent of the stand basal area. Conifers typical of higher elevations, such as Engelmann spruce, blue spruce, and/or subalpine fir may occur as "accidentals," or provide less than about 5% cover in late successional stands.

Layser and Schubert (1979), Moir and Ludwig (1979), Alexander et al. (1984a, b), Alexander and Ronco (1987), Youngblood and Mauk (1985), DeVelice et al. (1986), and Fitzhugh et al. (1987) all discussed classification of forest types in general or mixed-conifer forest types in particular in the southwestern United States. These treatments vary somewhat, possibly because of regional differences in forest types. A general consensus, however, indicates that mixed-conifer forest types generally fall in the following four series: *Abies concolor, Psuedotsuga menziesii, Pinus flexilis,* or *Picea pungens.*

Spruce-Fir

Spruce-fir forests in the southwestern United States generally coincide with the Subalpine Coniferous Forest discussed by Moir (1993). These are high-elevation forests occurring on cold sites. They have short growing seasons, heavy snow accumulations, and strong ecological and floristic affinities to cold forests of higher latitudes. Dominant trees include Engelmann spruce, subalpine and/or corkbark fir, or sometimes bristlecone pine. Moir and Ludwig (1979) included the *Picea engelmannii* and *Abies lasiocarpa* Series in the general spruce-fir forest type. Moir (1993) included the following series in this general forest group: Bristlecone pine, Engelmann spruce - bristlecone pine, corkbark fir - Engelmann spruce, Corkbark fir - Engelmann spruce - white fir, Engelmann spruce - Douglas-fir, and Engelmann spruce - limber pine.

Other Forest Types of Interest

Chihuahua Pine

The *Pinus leiophylla* Series is described by Layser and Schubert (1979). This series typically contains a diverse mixture of conifers and evergreen oaks. The conifer component is extensive enough to characterize this series as forest rather than woodland. Dominant conifers are typically Chihuahua pine, Apache pine, and *P. ponderosa* var. *arizonica* (Layser and Schubert 1979). This series is Madrean in affinity and, within the U.S., is restricted to central and southern Arizona and southwestern New Mexico (Brown et al. 1980). Moir (1993) included this type in the Lower Montane Coniferous Forest group.

Quaking Aspen

Quaking aspen is a special feature of western landscapes. It is a major seral species in the following series: *Abies lasiocarpa*, *Picea pungens*, and *Abies concolor*. It is a minor seral species in the *Picea engelmannii*, *Pseudotsuga menziesii*, and *Pinus ponderosa* Series (Larson and Moir 1986). As such, quaking aspen should be a common component of these landscapes under natural disturbance regimes.

Riparian Forests

Numerous authors have discussed classification and ecology of riparian forests in the southwestern United States (e.g., Pase and Layser 1977, Layser and Schubert 1979, Brown et al. 1980, Medina 1986, Szaro 1989). In general, southwestern riparian forests are dominated by various species of broadleaved deciduous trees and shrubs. Trees common in adjacent uplands, such as conifers, oaks, and quaking aspen, may occur in association with riparian trees, but generally do not dominate the site (Brown 1982).

PLAN DEFINITIONS

Our classification scheme is primarily concerned with a subset of the available forest types in the southwestern United States. We are interested in both potential and existing vegetation. Consequently, our scheme is a hybrid of classification schemes based on potential vegetation (series, association and habitat type) and forest cover types based on existing vegetation.

Three terms used in our definitions require clarification here. These are "pure," "majority," and "plurality." Various definitions exist to describe what constitutes a pure stand. Daniel et al. (1979) described pure stands as those where ≥90% of the dominant or codominant trees are of a single species. A stand may have an understory of other species without changing the pure designation. The key to this concept is the distinction between the dominant and codominant species and the understory component. In contrast, Eyre (1980) defined a pure stand as one where ≥80% of the stocking is by one species.

For purposes of this plan, we use the term pure to refer to any stand where a single species contributes ≥80% of the basal area of dominant and codominant trees. We use the term majority to refer to the situation where a single species contributes ≥50% of the basal area (Eyre 1980). We use the term plurality to refer to the situation where a species (or group of species of interest) comprises the largest proportion of a mixed-species stand (Eyre 1980).

With these definitions and concepts in mind, definitions for specific forest cover types are provided below.

Ponderosa Pine Forest

We define the Ponderosa Pine Forest Type as:

1. Any forested stand of the *Pinus ponderosa* Series not included in the Pine-Oak Forest Type (see below), or:

2. Any stand that qualifies as pure (Eyre 1980) ponderosa pine, regardless of the series or habitat type.

Pine-oak Forest

A number of habitat types exist in the southwestern United States that could be described as pine-oak. Most of the stands relevant to recovery of the Mexican spotted owl fall within two series, the *Pinus ponderosa* Series and the *Pinus leiophylla* Series. Present evidence, however, suggests that the former series includes many areas that could never attain the type of forest structure sought by spotted owls for roosting and nesting. Therefore, in an attempt to avoid needlessly restricting management options on lands not used to any great extent by the spotted owl, we propose the following operational definition for pine-oak forest under this Plan:

1. Any stand within the *Pinus leiophylla* Series.
2. Any stand within the *Pinus ponderosa* Series that meets the following criteria simultaneously:
    a) Habitat types that reflect *Quercus gambelii* or a *Quercus gambelii* phase of the habitat type.
    b) The stand is located in either the Upper Gila Mountains Recovery Unit, the Basin and Range-West Recovery Unit, or the Zuni Mountains or Mount Taylor regions of the Colorado Plateau Recovery Unit.
    c) ≥10% of the stand basal area or 2.3 m^2/ha (10 ft^2/ac) of basal area consists of Gambel oak ≥ 13 cm (5 in) diameter at root collar.
3. Any stand within the Basin and Range-West Recovery Unit of any other series that meets the following criteria simultaneously:
    a) A plurality (Eyre 1980) of the basal area exists in yellow pines (ponderosa, Arizona, Apache, or Chihuahua).
    b) ≥10% of the stand basal area or 2.3 m^2/ha (10 ft^2/ac) of basal area consists of any oaks ≥ 13 cm (5 in) diameter at root collar.

Mixed-conifer Forest

Natural variability is high within this forest type and has been increased by both natural and human-caused disturbances. Despite this variability, an extant classification scheme based on series and habitat types (Hanks et al. 1983, Layser and Schubert 1979, Alexander et al. 1984 a, b; Alexander and Ronco 1987, Youngblood and Mauk 1985, DeVelice et al. 1986, Fitzhugh et al. 1987) is available. This classification system is in widespread use and has multiple-agency support. Given that background, we propose using that system as a starting point in defining mixed-conifer forest, with some added refinements. Specifically, we propose that:

1. The definition of mixed-conifer forest generally be confined to the following series (Layser and Schubert 1979) and associated habitat types (after authors listed above): *Abies concolor, Pseudotsuga menziesii, Pinus flexilis*, or *Picea pungens*.

Within this framework, we provide the following exceptions to the general guideline listed above:

1. Any stand within the *Pinus aristata, Picea engelmannii*, or *Abies lasiocarpa* Series not having a plurality (Eyre 1980) of basal area of any of *Pinus aristata, Picea engelmannii, Abies lasiocarpa*, or *Pinus ponderosa*, singly or in combination, should also be defined as mixed-conifer.
2. Stands that can be described as "pure" for coniferous species other than Douglas-fir, white fir, southwestern white pine, limber pine, or blue spruce should be excluded from the broad category of mixed-conifer for the purposes of Plan implementation regardless of the series or habitat type. By pure, we mean that one species comprises 80% or more of the dominant and codominant trees (Eyre 1980).

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3. Stands of mixed species with ≥50% of the basal area consisting of quaking aspen should be defined as quaking aspen for the purposes of Plan implementation regardless of the series or habitat type.

High-elevation Forests, Including Spruce-fir Forest

We define this forest type as:

1. Any stand of the *Pinus aristata, Picea engelmannii*, or *Abies lasiocarpa* Series that meets the following criteria:
   a) The majority (Eyre 1980) of stand basal area consists of any of the three species listed above, either singly or in combination, or;
   b) Any stand that qualifies as a pure stand (Eyre 1980) of any of these species, regardless of the series or habitat type.

Quaking Aspen

We propose that any stands with ≥50% of the basal area consisting of quaking aspen be defined as quaking aspen.

KEY TO FOREST COVER TYPES

1. Trees deciduous and broadleaved, often confined to floodplain, drainageway, or canyon bottom (Layser and Schubert 1979) . . . . **Riparian Forest**

1. Dominant trees evergreen and needle-leaved 2

    2. Series = *Psuedotsuga menziesii, Abies concolor, Pinus flexilis*, or *Picea pungens* 3

    2. Series not as above 5

3. ≥80% of dominant and codominant trees are species other than *Pseudotsuga menziesii, Abies concolor, Pinus strobiformis, Pinus flexilis*, or *Picea pungens* . . . . **Classify by dominant species**

3. Stand not as above 4

    4. *Populus tremuloides* contributes ≥50% of stand basal area . . . . **Quaking Aspen Forest**

    4. Not as above. . . . . . . **Mixed-conifer Forest**

5. Series = *Pinus leiophylla* . . . . . . **Pine-oak Forest**

5. Series not as above 6

    6. Series = *Pinus ponderosa* 7

    6. Series not as above 10

7. Habitat type or phase includes *Quercus gambelii* 8

7. Not as above. . . . . **Ponderosa Pine Forest**

    8. Area is located within Upper Gila Mountains Recovery Unit, Basin and Range-West Recovery Unit, or the southeastern portion of the Colorado Plateau Recovery Unit (Zuni Mtns., Mt. Taylor). 9

    8. Area not located as above. . . . . **Ponderosa Pine Forest**

9. ≥10% of stand basal area or 2.3 m²/ha (10 ft²/ac) consists of *Quercus gambelii* ≥ 13 cm (5 in) diameter at root collar. . . . **Pine-oak Forest**

9. Not as above . . . . **Ponderosa Pine Forest**

10. Series = *Pinus aristata, Picea engelmannii*, or *Abies lasiocarpa* 11

10. Series not as above 13

11 Stand can be defined as pure for either *Pinus aristata, Picea engelmannii*, or *Abies lasiocarpa* . . . . **Spruce-fir Forest**

11 Stand not as above 12

12. *Pinus aristata, Picea engelmannii*, or *Abies lasiocarpa* contribute ≥50% of stand basal area, either singly or in combination. . . . . . . **Spruce-fir Forest**

12. Stand not as above . . . . **Mixed-conifer Forest**

13. Stand located in Basin and Range-West Recovery Unit 14

13. Stand not located as above . . . . . . **Other**

14. A plurality of stand basal area is contributed by *Pinus ponderosa, Pinus engelmannii*, or *Pinus leiophylla*, either singly or in combination 15

14. Stand not as above . . . . **Other**

15. ≥10% of stand basal area or 2.3 m²/ha (10ft²/ac) consists of any oak ≥ 13 cm (5 in) diameter at root collar. . . . . **Pine-oak Forest**

15. Stand not as above . . . . **Other**

D. CONCEPTUAL FRAMEWORK FOR RECOVERY

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The goal of this Recovery Plan is to recover the Mexican spotted owl so that it no longer requires protection under the Endangered Species Act. We submit that this can be best achieved by ensuring a mosaic of all successional stages, now and in the future, throughout a landscape comprised of all known habitat types used by the owl. In mixed-conifer, pine-oak and riparian forests, this habitat mosaic must contain stands adequate for all life-history requirements, including nesting and roosting.

We agree with the widely held belief that conditions within some southwestern forests deviate substantially from those existing prior to European settlement. Moreover, forests throughout the U.S. range of the owl are at high risk from fire, insects, and disease. The mechanisms responsible for current condition are not completely known, but synergistic effects of past timber harvest, overgrazing, and fire suppression are plausible explanations. The intent of this Recovery Plan is not to cast blame on any particular aspect of past management, but to outline the appropriate steps needed to ensure persistence of the Mexican spotted owl. Thus, the basis to maintain owl populations is to ensure that adequate habitat quality and quantity will be sustained through time. These conditions also must be within the natural range of variation.

We recognize, however, that major knowledge gaps preclude accurate descriptions of the natural range of variation and presettlement conditions. We cannot verify that fewer owls exist today than 100 years ago, or vice versa. We know little about habitat quality and how contemporary landscapes and ecosystem conditions contribute to owl fitness and population persistence. Thus, management of the owl should proceed in an iterative fashion. We must use the best available knowledge to guide current management, recognizing that new information from research and monitoring is critical for the development of long-term management plans.

This Recovery Plan details a short-term (10-15 years) strategy aimed at maintaining owl habitat where it exists and initiating a process to develop a forested landscape that includes replacement habitat. We presently have insufficient knowledge to design a strategy that will answer all long-term considerations, such as allocation of stand structures in space and time. Under proposed delisting criteria (III.A), the owl could be delisted within this 10-15 years, rendering this plan obsolete.

To achieve the recovery goal [illegible] Plan, management must [illegible] tem processes and landscape mosaics that balance natural variability and secure the landscape against catastrophic habitat loss. Our recommendations assume that population status and habitat condition will be monitored in conjunction with recovery efforts for the Mexican spotted owl (Part III). The management recommendations are not meant to stand alone without such monitoring.

ECOSYSTEM OR LANDSCAPE MANAGEMENT

Volume 2 summarizes current knowledge of the Mexican spotted owl's basic natural and life histories, but a brief reiteration is appropriate here. First, the owl is found in a number of different habitat types ranging from slickrock canyons to cool, mesic forests. Second, the owl has relatively large home ranges, typically containing mosaics of vegetation types and different seral stages and conditions within those types. Third, the owl takes numerous species of prey and each of these species has unique habitat requirements. These factors considered simultaneously stress the need to consider management across spatial scales ranging from sites to landscapes and to provide the diversity of conditions required for the owl's life history. Consequently, we submit that management for Mexican spotted owls must be viewed within the context of managing ecosystems.

How can ecosystem management be applied to the Mexican spotted owl? Ecosystem management should sustain biotic diversity and the natural processes and landscape mosaics that generate that diversity (cf., Jensen and Bourgeron 1993, Franklin 1993, 1994; Diaz and Apostol 1993, Kaufmann et al. 1994, Williams 1994). The current emphasis in ecosystem management is to use the filter approach described by Hunter (1991). Two "sizes" of filters, coarse and fine, are used.

The objective of the coarse filter approach is to maintain the natural array of conditions that exist within the biotic and physical limits of the landscape. This would include special as well as common habitats. Ideally, the array of conditions provided by using the coarse-filter approach should maintain most plants and animals adapted to natural conditions (Hunter 1991). This should include most of the habitat conditions needed by the owl and its prey.

In some cases, however, a fine filter may be required for specific habitats, or habitat elements, that fall through the coarse filter. With respect to the Mexican spotted owl, the coarse filter is probably sufficient for most foraging habitats, but a fine filter may be needed to provide nest and roost sites. For example, the owl prefers or needs particular landforms (such as steep-walled canyons), particular structures (including snags, large trees, large logs, cavities and other platforms for nesting), mature forests, and specialized microhabitats. Thus, a fine-filter analysis is required to identify and ensure continuing availability of the owl's specific habitat needs.

In summary, the coarse filter approach is used to manage the overall landscape, and, if properly applied, should suffice to maintain the natural array of conditions on that landscape. The fine filter is used to provide specialized habitats or habitat elements within that overall landscape.

Two themes of the recovery measures are consistent with these principles of ecosystem management. The first theme is that the general recommendations of this Recovery Plan provide conditions for the owl across the landscape. This landscape should provide nesting, roosting, foraging, and dispersal macrohabitats in the short term. This theme emphasizes protecting and monitoring owl populations and habitats.

The second theme acknowledges that ecosystems are temporally dynamic, and that provisions are needed to ensure owl habitat in the long term. As nest sites change and are abandoned, new nest sites should develop and become occupied. Allocation of mid- to late-seral forests needed by spotted owls, and other species, in future decades requires knowledge of forest disturbances, risks, and rates of succession at different spatio-temporal scales. We outline below some disturbances, risks, and tools that should be considered in managing present and future owl habitat.

Fire

Fire is the most rapidly acting of natural disturbances. A crown fire can quickly consume forests across vast tracts. After a large crown fire, habitat components for nesting, roosting, and foraging are reduced or eliminated. Small-scale natural fires and prescribed burns, however, can reduce fuel loadings and create small openings and thinned stands that increase horizontal diversity and reduce the spread of catastrophic fire. Small-scale fires and lightning also create snags, canopy gaps, and large logs, plus they perpetuate understory shrubs, grasses, and forbs which are important habitat components to the owl, its prey, and other wildlife. Under natural fire regimes prior to 1890 these small fires occurred frequently (Moody et al. 1992).

The risk of catastrophic fires is widespread in Southwestern forests and woodlands (Moody et al 1992). Fuel accumulations and forests overstocked with trees place spotted owl habitat at risk with respect to stand-replacing fires. Figures II.D.1-3 show the changing fire record from 1910 to 1992, based on records compiled at the FS Southwestern Regional Office. Because FS burn policies changed during this period and the use of prescribed natural fire increased, interpretation of these records is not straightforward. In general, however, the figures document an increase in both area burned per year and in area lost to catastrophic, stand-replacing fires.

The number of total natural and human-caused fires generally declined after 1981 (Figure

II.D.1), but the number of large fires (> 4 ha [>10 acres]) increased at the same time (Figure II.D.2). Figure II.D.3 shows the trend clearly: from 1985 to 1992 the number of hectares that burned increased. If the influence of two exceptional fire years (1974 and 1979) is removed, the trend shown in Figure II.D.3 remains; that is, the number of large fires increased.

Moody et al. (1992) estimated that about 303,500 ha [750,000 acres] of mixed-conifer forest within FS Region 3 needed treatment to reduce fire risk in the next 10 years. Unmanaged and unplanned conversion of large areas of forests or woodlands to early seral conditions by wildfire can disrupt management goals to maintain existing and to provide future spotted owl habitat (USDA 1993c).

Characteristics of many nest and roost sites of spotted owls place them at high fire risk. Some nest/roost locations at special topographic locations (such as steep-walled canyons or isolated places) may be fire refugia, however. Taking cue from these, one promising management tactic is to isolate nest/roost sites from the adjoining high-risk forest by reducing flammability and fire spread in a buffer around the site. This must be done, of course, without compromising the site itself as nest/roost habitat.

Inevitably, severe climatic conditions will occur in the future, and extreme fire years are possible (Swetnam and Betancourt 1990). Given the present conditions of Southwestern forests, extreme fire years could result in holocaustic fires throughout large portions of the owl's range. Because the resulting damage to owl habitat would be irreparable in the forseeable future, efforts to limit large-scale catastrophic fires are of utmost importance for owl conservation.

Increased use of fire and other tools will be needed to reduce the amount of forest at high risk from stand-replacing fires. The Recovery Team encourages proactive fire management programs which assume active roles in fuels management and understanding the ecological role of fire. An example of such a program is the one employed by the Gila National Forest.

The Recovery Team recognizes that fire technology may not be at the level of sophistication needed to maintain owl habitat and create new habitat. Although we advocate broadscale use of fire in the Southwest, we also stress the need to approach the use of fire in an adaptive management context. Prescriptions that maintain key structural features of owl and small prey habitats should be developed and tested. These features include large trees (which are often fire resistant), snags, logs, and understory hardwood trees. Treatments to produce or maintain such habitat components must be assessed by monitoring to evaluate if treatment objectives were met in both short and long terms. Wholesale use of fire without understanding or monitoring its effects on habitat may render areas unusable by owls, and may also miss opportunities to improve our knowledge of fire effects. Fire and wildlife personnel should work together to refine fire prescriptions compatible with maintenance of important habitat elements.

Other Natural Disturbances

The vegetative communities that provide habitat for the Mexican spotted owl are dynamic assemblages of living plants, snags, logs, and numerous organisms active in decay and nutrient-cycling processes. Herbivory, disease, and structural change caused by bacteria, fungi, insects, and vertebrates are natural agents of change in forest and woodland communities and occur at scales ranging from individual trees to landscapes.

These disturbances contribute to the formation of complex landscape mosaics in which woodlands and forests consist of aggregates of transient patches and gaps. Added to this patchiness are changes of the structural elements of owl habitat caused by disturbances at scales larger than gaps. Climate change, pollutants, and other extensive events will produce effects of magnitudes that are poorly understood (Davis 1989). Although management scarcely influences the primary determinants of vegetation pattern (geology, climate, and genetics), management can affect vegetation by manipulating the extent, severity, and frequency of disturbance.

Land managers should recognize that natural disturbances can create and maintain diverse and productive ecosystems that *always* include, somewhere on the landscape, an adequate amount and distribution of the vegetative

Figure II.D.1. Historical record of number of total fires and number of natural fires. Data from USFS Southwestern Region.

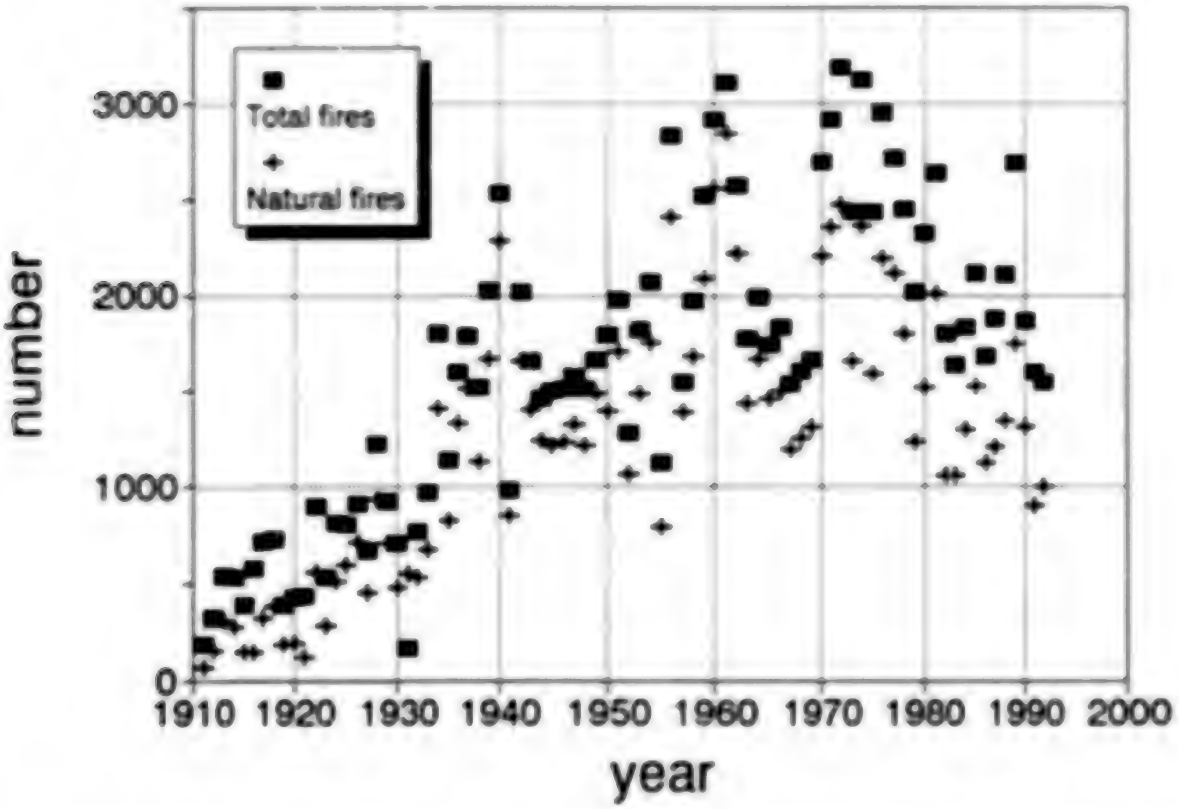


Figure II.D.2. Historical record of fires over four hectares in size. Shown are numbers of fires and area burned. Data from USFS Southwestern Region.

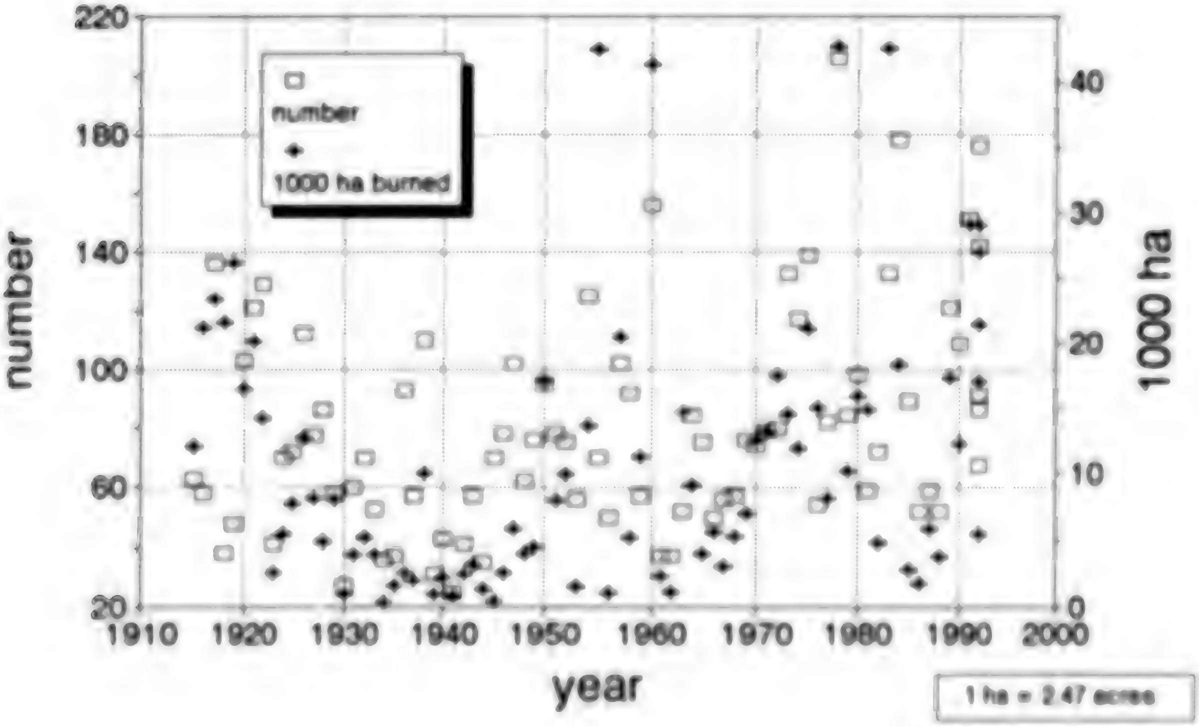
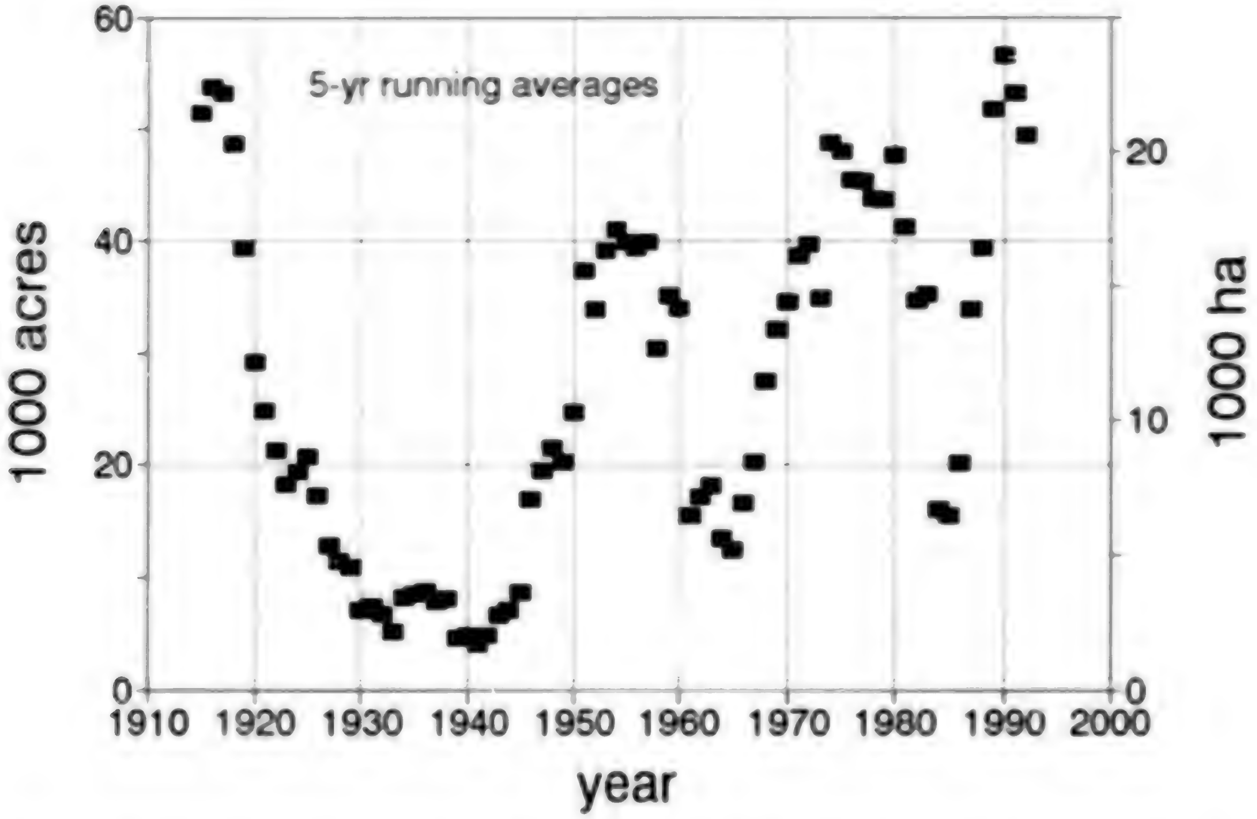


Figure II.D.3. Five-year running averages of area burned. Data from USFS Southwestern Regio



elements that are the required habitat for the Mexican spotted owl. The word "adequate" is crucial. Adequacy is derived from publicly acceptable landscape descriptions (desired conditions), together with use of the best succession, allocation, and landscape-dynamic models to guide managers in how to get there. Adequacy is tested by ongoing monitoring and adaptive management (III.C) and should not be assumed in the absence of monitoring.

Insects and microorganisms can be beneficial as well as destructive agents of plant succession (Dinoor and Eshed 1984, Knauer 1988, Dickman 1992, Haack and Byler 1993). These organisms may produce large-scale community changes after periods of climatic stress that "predispose" forests to insects or pathogenic occurrences (Colhoun 1979). Several groups of forest insects occasionally develop epidemic populations that severely damage mature forest trees over large areas. Among the defoliating insects, the western spruce budworm kills understory white fir and Douglas-fir and thins the crowns of overstory trees (Archambault et al. 1994). Outbreaks of western spruce budworm occur every decade or so and extend widely across the landscape. Perhaps as a response to fire exclusion policies, recent budworm outbreaks have tended to be regionally synchronous with the maturing of host species over large areas (Swetnam and Lynch 1993). As a complicating factor, trees that suffer declining vigor from multiple years of defoliation by budworms may lose their resistance to more injurious wood-boring insects and ultimately die. Bark beetles are important wood-boring insects in pinyon, ponderosa pine, Douglas-fir, and Englemann spruce. During outbreaks (about every 7 to 10 years), these insects kill groups of mature trees. In longer outbreaks (usually those following droughts), mortality groups coalesce and damage appears to be widespread. Bark beetle populations are most likely to increase where host trees are stressed as a result of sublethal fire damage, dwarf mistletoe infection, or where abundant green slash is available from thinning or blowdown.

The principal forest pathogens are root disease fungi and dwarf mistletoe. *Armillaria* root disease is widespread across the forests of the Southwest. In a few locations it behaves as an aggressive killing agent (Marsden et al. 1993), but in most stands it acts to remove trees weakened by lightning or insects. Other root diseases are caused by *Heterobasidion annosum* and *Phellinus schweinitzii*.

The most common tree disease in Southwestern forests is caused by parasitic seed plants of the genus *Arceuthobium*, the dwarf mistletoes. About one-half to two-thirds of the stands in these forests are infested by dwarf mistletoe. Infected trees become stunted, develop witches' brooms, and are eventually killed by this or other mortality agents. Both root disease and mistletoe typically occur as "centers" or "patches" and create slowly but continously expanding canopy gaps. These agents increase ecosystem diversity by producing snags, logs, and, in the case of mistletoe, witches brooms. They also act synergistically with forest insects.

The relationship between fire and dwarf mistletoe is complex. Brooms caused by dwarf mistletoe provide fuel continuity from ground to tree crown. By maintaining seral trees in forest stands, fire increases the opportunity for mistletoe infection because the seral trees are more commonly hosts than climax trees. Similar complex relationships exist between fire, bark beetles, and western spruce budworms.

White pine blister rust is caused by an exotic fungus that was recently introduced into the Sacramento Mountains. It has the potential to kill most of the southwestern white pine in the mixed-conifer forests (Hawksworth and Conklin 1990) where the greatest concentration of Mexican spotted owls occurs. Although southwestern white pine is seldom the most frequent tree species of a stand, it is an important seral, dominant, or codominant species in most areas. This tree produces large seeds and readily fills gaps opened by mortality of other trees to budworm, bark beetles, root disease, and mistletoe. Therefore, the short-term effects of white pine blister rust may be negative, since a strong reordering of forest tree composition may take place. A number of actions can be taken to "control" the rust and reduce its impacts, but they are expensive and their effectiveness and possible side effects are unknown. In the long term, a genetic balance between the rust and white pines may occur, as it did with *Pinus monticola* in the northern Rockies (Ledig 1992).

Various other arthropods and saprophytic fungi are also important agents of deterioration and decay of snags and logs. Although these agents generally do not kill trees directly, their activity (decay) can lead to stem breakage and tree death. They are thus important in determining the condition and persistence of coarse woody debris within forest stands.

The cumulative impacts of these disturbance agents on owl habitat depends on a number of factors, some of which are subject to manipulation. In general, these and other kinds of disturbances affect forest nutrient and water cycles, solar penetration to the understory, and plant and animal food webs. The response of understory vegetation, fungal-small mammal relationships (Maser et al. 1978), and owl prey to various disturbance factors can be positive or negative, depending on numerous site factors and the successional stage of the affected vegetation. Because these processes are interactive and affect a number of vegetation attributes, simple assessments are inadequate. Several vegetation management tools, including various kinds of silviculture, risk-abatement for fire or insect/disease damage, prescribed burning, and direct population control are appropriate in various combinations.

These disturbance agents should be considered in developing management strategies for owl recovery. Managers must recognize that the organisms discussed above and their effects are not necessarily or even primarily bad. Certain natural processes may interfere with short-term priorities of forest management; but the perpetuation of forest conditions that support those priorities may depend on natural processes continuing in the long term. Moreover, conflicting priorities, or even second- or third-level priorities may benefit from these organisms. Evaluations should be based on the role these organisms play in directing succession toward, or away from, desired future conditions at different spatiotemporal scales.

Managers, in consultation with specialists, can use these organisms to strategic advantage in creating, enhancing, or maintaining habitats for owls (and associated biota) in accord with landscape goals. For example, dwarf mistletoe creates nest sites for owls in Douglas-fir. In some places, outbreaks of western spruce budworm eliminate understory host trees, helping to reduce fuel ladders that carry fires into tree crowns. These biotic agents of mortality have thinning effects on tree overstories. Such thinning affects nutrient and hydrological cycles, understory vegetation, and availability of prey to owls.

In summary, we encourage resource managers to work with forest insect and disease specialists to develop ecological assessments of these kinds of disturbances at various scales (Kaufmann et al. 1994). Understanding the scientific basis of forest change and evolution is crucial to successful management of forest ecosystems, and therefore to recovery of the spotted owl.

Degradation of Riparian Forests

Riparian forests may also function as important components of ecosystems supporting spotted owls. These communities, particularly mature, multi-layered forests, could be important linkages between otherwise isolated subpopulations of spotted owls. They may serve as direct avenues of movement between mountain ranges or as stopover sites where drainages bisect large expanses of landscape that otherwise would be inhospitable to dispersing owls. Further, historical evidence exists that spotted owls once nested in such habitats.

Many riparian ecosystems have deteriorated in the Southwest (Cooperrider 1991, Bock et al. 1993, USDI 1994), and the loss of riparian habitat was one of the reasons for listing the owl (Part I). Dick-Peddie (1993) estimated from map and air photo data that 96% of the Rio Grande riparian area in New Mexico has been lost to urbanization, agriculture, water impoundments, and other modifications. Gallery forests that once extended into woodlands, grasslands, and deserts have significantly declined or deteriorated, adversely affecting numerous wildlife populations (Minckley and Clark 1984, Skovlin 1984, Minckley and Rinne 1985, Bock et al. 1993, USDI 1994). Efforts to improve riparian and watershed conditions (DeBano and Schmidt 1989a, 1989b) could facilitate movements of spotted owls between distant geographic locations and perhaps even provide nesting habitat. A wide variety of other organisms would also benefit from healthier riparian systems.

TIMBER HARVEST AND SILVICULTURAL PRACTICES

Historically, the principal objectives of forest management were to derive economic gain and commodities from forests. Silviculture has great potential as a tool for meeting other objectives, however, such as maintaining and developing Mexican spotted owl habitat, alleviating fire risk, minimizing impacts of insects and disease, and enhancing various ecological values. In this section, we review past timber-harvest practices in the Southwest and contrast those practices with alternatives. Our focus is the potential effects of these practices on Mexican spotted owls.

Historical Perspectives

Past Practices

The primary factors leading to the listing of the Mexican spotted owl were adverse modification of its habitat as the result of even-aged management and plans to continue this harvest method as detailed in existing Forest Plans. Fletcher (1990) reported the loss of >325,000 ha (800,000 acres) of spotted owl habitat within FS Region 3 as the result of human activities, primarily forest management. Silviculture emphasized even-aged systems which tended to simplify stand structure and harvest a disproportionate share of large trees. The Team used past forest inventory data to evaluate the change in the size-class distribution of trees from the 1960s to the 1980s. The trend that emerged from our analysis was a substantial increase in the density of trees 12.7-32.8 cm (5-12.9 in) dbh, but a large decrease in numbers of trees ≥48.3 cm (19 in) dbh (see below). As discussed by Ganey and Dick (1995), large trees are an important component of spotted owl habitat; thus, the 20% decrease in numbers of trees ≥48.3 cm (19 in) dbh removed a key habitat component of the Mexican spotted owl. The simplification of stand structure is not so easily quantified. Given that mostly even-aged management was used, however, the conclusion of stand simplification is reasonable.

Forest Plans

Existing Forest Plans and their underlying standards and guidelines are fairly explicit with respect to the silvicultural practices to be used and the expected timber volumes to be extracted. These Forest Plans articulate classic even-aged management regimes with regeneration treatments occurring at 120-year intervals, intermediate treatments employed to maintain open stand conditions, and disease-control treatments as conditions warrant. Thus, management called for fairly frequent entries into a stand. Further, this management system stressed simple stand structures, decreased residual densities, and elimination of large, slow-growing, but high value trees (primarily ponderosa pine and Douglas-fir). Salvage, sanitation, fuel reductions, and fuelwood harvest as specified in Forest Plans combined to reduce numbers of snags, another correlate of spotted owl habitat. In summary, even-aged management as specified in Forest Plans is incompatible with maintaining and developing spotted owl habitat. The Team is encouraged, however, by recent efforts by FS Region 3 to amend forest plans to incorporate the recommendations proposed in this Recovery Plan, and to emphasize uneven-aged management as the preferred silvicultural system in the Region.

Habitat Trends

Historical and current trends in spotted owl habitat are presently unknown. Numerous factors underlie this lack of knowledge, but the paucity of reliable vegetation data is the most glaring explanation. This lack of credible data has not precluded rampant speculation on habitat trend, however. In general, habitat trend is perceived in two divergent ways. One view is that past timber harvest within the forest types used by Mexican spotted owls has caused a dramatic decline in habitat quantity and quality. Indeed, the conclusion of historical habitat loss coupled with projections for additional habitat loss were the primary factors for listing the subspecies (Part I). The contrary view suggests that many years of fire exclusion within Southwestern forests has allowed mixed-conifer forest types to increase at the expense of meadows and fire-disclimax species such as quaking aspen and ponderosa pine (USDA 1993b, Johnson 1994). Further, Southwestern ponderosa pine forests are known to be generally denser today than they were in pre-settlement times (Covington and Moore 1992, 1994a, b, c). Based on this information, USDA (1993b) concluded that habitat suitability for the Mexican spotted owl had increased. Because of these conflicting views, the Team attempted a quantitative evaluation of habitat trend with respect to the Mexican spotted owl.

Data Availability.—Limited sources of data are available for assessing habitat trend. Within forested types, forest inventories from the 1960s (Choate 1966, Spencer 1966) and the 1980s (Conner et al. 1990, Van Hooser et al. 1993) have been compared by USDA (1993b) and Johnson (1994) and are used, in part, for our analyses. We admit, however, that differences in definitions and in how data were collected make comparisons between the 1960s and 1980s data tenuous, at best (Van Hooser et al. 1993). These differences include: (1) changes in definitions of vegetation types; (2) changes in the landbase being sampled, (e.g., changes in wilderness designation); and (3) changes in sampling intensity.

The following comparisons are limited to commercial forest lands within the States of Arizona and New Mexico on a per hectare basis. Thus, all forest types are included but, unlike USDA (1993b) and Johnson (1994) we do not extrapolate the data to unsampled forested lands such as wilderness areas. Therefore, our analyses focus on changes on commercial forest lands where data exist. Because of differences in land designations (i.e., commercial timber land becoming wilderness between the two sampling periods), comparisons of raw values are potentially misleading. Thus, our comparisons are primarily restricted to evaluations of proportions. To compare stand structure, we used relative frequencies of trees by size class. We reiterate that caution is warranted when inferring conclusions from these data, but submit that some gross generalizations are possible.

Trends in Forest Landbase and Timber Volume.—Total forested land increased from 4,516,000 to 4,750,000 ha (11,160,000 to 11,738,000 acres) from the 1960s to the 1980s, roughly a 5% increase. The commercial forest landbase decreased by approximately 15% (624,000 ha [1,541,000 acres]), however, and reserved forested lands increased by 858,000 ha (2,119,000 acres). Growing stock (i.e., the harvestable volume) on commercial lands decreased from 12,707 MMCF to 11,549 MMCF. This decrease is not surprising given the volume of timber harvested on commercial forest lands and the decrease in the amount of commercial forest lands from the 1960s to the 1980s.

Trends in Forest Types.—Within the commercial landbase, mixed-conifer forests comprised approximately 11% of total area in the 1960s and 20% of the total area in the 1980s, a 9% increase (Table II.D.1). Possible explanations for this change include: (1) increasing invasion of mixed-conifer species (presumably Douglas-fir and white fir) into other types, such as meadows; (2) more liberal definitions of mixed-conifer (i.e., includes types previously classified as something else); (3) quaking aspen giving way to other species in the absence of fire; and (4) selective harvest of ponderosa pine, leaving residual forests composed primarily of other conifer species. Any of these reasons may explain the perceived changes of forest type; probably all of these and other factors contributed to some degree. We speculate that classification changes account for most of the change, and that selective removal of ponderosa pine and the succession of quaking aspen stands to mixed-conifer are also plausible short-term explanations. Conversely, we have difficulty accepting that encroachment of mixed-conifer species into other forested types was responsible for more than a relatively small portion of this change within the twenty-year period. Thus, any generalizations concerning changes in forest types and any actions proposed to reverse these trends

Table II.D.1. Changes in the area (ha X 1,000 [acres x 1,000]) and distribution of forest types from the 1960s to 1980s on commercial forest lands within Arizona and New Mexico. Data from Choate (1966), Spencer (1966), Conner et al. (1990), Van Hooser et al. (1993).

Forest Type	Landbase in 1960s[a]	Proportion of 1960s Landbase[b]	Landbase in 1980s[a]	Proportion of 1980s Landbase[b]	Change in Proportion[c]
Ponderosa Pine	3,234 [7,992]	78	2,530 [6,252]	72	-6
Mixed-conifer	475 [1,173]	11	709 [1,752]	20	9
Spruce-fir	257 [635]	6	201 [496]	6	0
Quaking aspen	180 [446]	4	81 [201]	2	-2
Total	**4,146 [10,246]**	**100**	**3,523 [8,701]**	**100**	

[a] Landbase in hectares [acres] covered by the forest type

[b] Proportion of the total forested landbase belonging to the forest type

(Prop. 1960s landscape)-(Prop. 1980s landscape)

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Table II.D.2. Changes in the density (trees/ha [trees/acre]) and distribution of tree size classes from the 1960s to 1980s on commercial forest lands within Arizona and New Mexico. Data from Choate (1966), Spencer (1966), Conner et al. (1990), Van Hooser et al. (1993).

Tree Size Class	Density in 1960s[a]	Proportion of 1960s Total[b]	Density in 1980s[a]	Proportion of 1980 Total[b]	Change in Proportion[c]	Density Change[d]
2.5-12.5 cm [1.0-4.9 in]	146.2 [59.2]	62.5 [54.3]	134.2	53.7	-8.8	-8.3
12.6-32.8 cm [5.0-12.9 in]	70.3 [28.5]	30.0 [39.9]	98.5	39.4	9.4	40.2
32.9-48.0 cm [13.0-18.9 in]	12.1 [4.9]	5.2 [5.3]	13.0	5.2	0.0	7.5
>48 cm [>19 in]	5.4 [2.2]	2.3 [1.7]	4.3	1.7	-0.6	-20.4

[a] Tree density in no./ha [no./acre]

[b] Proportion of the total number of trees within that size class

(Prop. 1960s total)-(Prop. 1980s total)

[d] ([Prop. 1960s total]-[Prop. 1980s total])/(Prop. 1960s total)

must acknowledge this uncertainty, and should consider all plausible explanations for these trends.

Trends in Size-class Distributions.—We noted a change in the size-class distribution of trees on commercial forest lands of Arizona and New Mexico (Table II.D.2). Sapling-sized trees (2.5-12.5 cm [1-4.9 in] dbh) decreased in both absolute density and in relative contribution to the size-class distribution; trees 12.6-31 cm (5-12 in) dbh increased in density by 40% and in relative proportion of the size class distribution by >9%; and trees in the 31-48 cm (13-19 in) size class increased in density but not in relative proportion of the tree distribution. Finally, the density of large trees (>48 cm [19 in] dbh) decreased from 2.3 to 1.7 trees/ha (0.9 to 0.7 trees/ac), a 20% decline. This decrease in large trees would be expected given past timber harvest practices which emphasized harvest of the large trees. Possible explanations for the increase in smaller stems include the growth of regeneration, limited pre-commercial thinning, fire suppression, and the lack of interest by the forest industry in the smaller-sized stems.

Summary of Recent Habitat Trends.—Our analyses indicate that between the 1960s and 1980s (1) total forested acres increased, (2) mixed-conifer types apparently covered more of the landbase (but see above cautions regarding this conclusion), and (3) densities of large trees declined. Although the amount of total forested land has increased and the amount of mixed-conifer forest may have increased, we doubt that the amount of Mexican spotted owl habitat has increased concomitantly. Given the 20-yr period between inventories, most of these additional acres are likely in early successional stages and unlikely to possess the habitat characteristics used by spotted owls. Conversely, the 20% decrease in the density of large trees is an alarming negative trend with respect to a very critical component of spotted owl habitat.

Silvicultural Practices and Forest Management

Four common forest structures occur naturally or by silvicultural efforts. These structures are even-aged, balanced uneven-aged, irregular uneven-aged, and even-aged/uneven-aged stratified mixtures. Even-aged stands, for the most part, are characterized by most trees being approximately the same age. The general convention is that the spread of ages within the stand are within approximately 20% of the specified rotation age. Two types of uneven-aged stands are balanced and irregular stands. In both cases, at least three distinct age classes exist. A balanced uneven-aged stand equates to each age class occupying roughly equal areas. Distribution by diameter class approximates a reverse, j-shaped curve. Irregular uneven-aged stands have some age and associated diameter classes missing across the possible range of ages and diameters. A two-storied stand, one with two distinct age-class and diameter distributions, is neither even- or uneven-aged, but is intermediate between the two. Stratified mixtures occur where trees are essentially even-aged, but differences in growth rates and shade tolerance among tree species result in multiple canopy strata. This structure also occurs when selective regeneration of shade-tolerant species or high site productivity leads to heterogeneous age and diameter distributions. In much of the mixed-conifer type in the Southwest, the stratified-mixture of stand structure appears to be relevant to habitats used by spotted owls.

Silviculture

Silviculture has been variously defined as (1) the art of producing and tending a forest, (2) the application of knowledge of silvics in the treatment of a forest, and (3) the theory and practice of controlling forest establishment, composition, structure and growth (Smith 1986). In a general sense, silviculture is the practice of managing forest establishment, composition, structure, and growth to meet stated objectives. Thus, silviculture should be regarded as a system of treatments and not solely the practice of removing trees from a stand.

In the Southwest, two broad classifications of silvicultural systems, based on methods of reproduction and resulting age-class mixes of forested stands, are even-aged and uneven-aged management. These are reviewed below; again, our focus is the potential these systems have for developing spotted owl habitat.

Even-aged Management.—Even-aged management has been used commonly in Southwestern forests. Reasons for its popularity are based both on ecology and economics. Ecologically, even-aged systems favor species with limited shade tolerance, such as quaking aspen, oaks, and lodgepole pine. Shade tolerance is the ability to reproduce and grow under the shade of larger, taller trees. Shade-tolerant species typically include true firs in Southwestern forests. Ponderosa pine is considered to be of intermediate shade tolerance, but tending toward the intolerant side. Economically, even-aged management is more efficient when considering short-term costs of site utilization, sale preparation, transportation systems, harvesting, and slash reduction. Further, even-aged systems are easier to model, administer, and track over time.

Regeneration methods within even-aged systems of the Southwest include shelterwood, clearcutting, and seed tree methods. The shelterwood method typically has a series of cuttings. The first treatment in mature stands is to stimulate cone and seed production for regeneration. This is followed by a series of treatments that remove the larger, older stems as regeneration matures. Variations on the general method include irregular shelterwood and group-shelterwood. Clearcutting involves the removal of the entire stand in one cutting. Reproduction is obtained artificially by seeding or planting, or naturally by seeding from adjacent stands. This method is appropriate for shade-intolerant species. In appearance, clearcutting is indistinguishable from the coppice-forest method of regeneration for quaking aspen, where reproduction is obtained from suckering of sub-terrain clones. The seed-tree method resembles clearcutting except that a few trees are left to provide a source of seed within the treated area. Of these three, the shelterwood method is used most commonly in the Southwest; clearcut and seed-tree methods are used infrequently.

Variations of even-aged management are used throughout the Southwest, but all share the following characteristics. A predetermined time for regeneration of the stand is set *a priori*; this regeneration time can vary. The FS Region 3 generally schedules regeneration treatments from 100 to 120 years of stand age, an age when trees are expected to reach 45.7 cm (18 in) dbh as the maximum size. The management objective is to maximize total volume over time while provid-

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ing a "saw-timber" sized product. Residual stand density can be controlled by thinning at theoretically scheduled entries in the stand. This enables the capture of mortality on a semi-regular basis and provides intermediate revenues from timber harvest.

Even-aged stand structures are not used to any great extent by the Mexican spotted owl. Further, with its intent to promote uniformity in tree age, size, spacing, and density, even-aged management generally would not be a preferred system for short-term development of spotted owl habitat. Even-aged management may be appropriate to maintain quaking aspen within the mixed-conifer type, however. Quaking aspen is typically even-aged in its earlier stages of stand development. Because of its extreme shade intolerance and requirements for elevated soil temperatures for sprouting, quaking aspen should be managed under even-aged systems. Later seral stages of quaking aspen that include a mixed-conifer understory appear both as a simple mixture of an even-aged overstory and uneven-aged understory, or as a stratified mixture. As decadent quaking aspen stands are replaced by the shade-tolerant conifers, spotted owl nesting/roosting habitat begins to develop. In summary, even-aged management has limited potential with respect to developing the types of stand structures used by spotted owls. Nevertheless, even-aged management is a critical tool to meet specific objectives, and can meet certain ecosystem objectives if employed at the proper scale. Perhaps the primary objection to its use in the past was its uniform, widescale application across the Southwest.

Uneven-aged Management.—Uneven-aged management entails the removal of timber in all size classes on a periodic basis so that regeneration is continuously established over time, and stand size-class distribution is regulated. Uneven-aged management is loosely based on the premise that density control across a range of diameter classes will ensure growth of stems over time to a set maximum diameter, while ensuring regeneration of species at regular intervals over time. Only one reproduction method, the selection method, is used with uneven-aged management. The selection method provides openings in the stand to enable regeneration to occur. Simultaneous with the selection and harvest of trees to provide growing space for regeneration, trees across all diameter classes are thinned to ensure the desired distribution of size- and age-classes within the stand.

Two variations of the selection method are individual tree selection and group selection. Individual tree selection, as the name implies, involves the removal of single, scattered trees. This method generally favors shade-tolerant species, but this is also a function of the residual stocking levels. Group selection entails the removal of a small patch of trees; the width of the patch is usually less than twice the height of the dominant (i.e., largest) tree. This is somewhat analogous to a very small clearcut, but the difference between the group selection and the clearcut method is in the spatial scale of application. Group selection is used to create a balance of age- or size-classes in small contiguous groups resulting in a mosaic within a stand. In contrast, even-aged methods are typically applied to an entire stand. Group selection can be used to promote the establishment and growth of shade-intolerant trees since there is opportunity to reduce localized residual densities and the amount of area shaded.

Group selection offers a number of advantages for the development of potential spotted habitat over single-tree selection techniques. Application of the group selection method could provide a mosaic of many small even-aged or two-storied groups across a forest stand. Regeneration of shade-intolerant species is possible where a reproduction source, either clones or seeds, is present. With respect to insect and disease problems, management options increase for both suppression and prevention, especially in mixed-species stands. Edge effects found at group interfaces can provide structural features and openings that mimic gap-phase regeneration, and provide early-seral vegetation for prey species (Ward and Block 1995). In some cases, group-selection methods may result in less residual damage to the stand as the result of logging activities than single-tree selection.

Uneven-aged silvicultural practices predominate on Tribal lands where commercial timber harvest exists. Reasons for the emphasis on this silvicultural system include aesthetics, providing forest cover over all lands simultaneously, the perception that it provides a more even-flow of products than even-aged management, and the fact that it allows continuous regeneration.

We have not been able to assess the effects of classic uneven-aged management on Mexican spotted owl habitat because we were unable to acquire data for most areas where uneven-aged management is practiced on a large scale. However, based upon our understanding of the application of uneven-aged systems, stand density is often kept at a fairly low level, seldom exceeding 18 m^2/ha (80 ft^2/acre) of basal area. These low residual stand densities allow for regeneration and growth of ponderosa pine. Uneven-aged systems, whether they retain individual trees or groups of trees, allow for the development of multiple canopy levels, a key component of Mexican spotted owl habitat. However, Ganey and Dick (1995) demonstrate clearly that owl habitat typically also includes significant numbers of large trees. These large trees may not be retained where uneven-aged management is applied in this fashion.

In summary, uneven-aged management has some promise for providing stands exhibiting characteristics of spotted owl habitat. As currently practiced, however, uneven-aged management results in large acreages of low-density stands, numerous road openings, and the eventual eradication of large diameter stems. Although neither the short- or the long-term effects of these applications on spotted owls are known, this type of application may not be the best option for producing spotted owl habitat.

Development or maintenance of stratified mixtures.—Stratified mixtures can originate in various ways, including stand-replacing events (e.g., crown fire, even-aged management) that may or may not leave remnant stems. The establishment of stratified mixtures is not likely in mixed-conifer types within the short time frame (10-15 years) of this Recovery Plan. Maintenance of such stands could be considered in the short-term, however, and development of stratified mixtures could be incorporated in longer-term management plans.

Management for stratified mixtures must consider the mix of species along the continuum of shade tolerance. Thus, any regeneration efforts should be designed to have enough openings of sufficient size for seedling/sprouting establishment and release. Openings can be accomplished by group selection cuts favoring retention of shade-intolerant species, or selection of individual trees adjacent to stems that could provide a seed source for regeneration. One technique to consider is small-scale seed tree cuts (perhaps to be thought of as group seed-tree selection cuts), which would provide both a seed source and trees for ultimate snag development. This method could maintain shade-intolerant species, but would not be intrusive enough to produce even-aged structure throughout the stand. Within stratified mixtures, intermediate treatments including pre-commercial and commercial thinning could be beneficial in increasing the growth of residual trees. At some point, however, further treatments should be deferred, and natural stand maturation and succession should be allowed to proceed until either (1) the stand is no longer spotted owl habitat; or (2) the stand can be replaced by habitat (preferably occupied by spotted owls) that has been developed elsewhere.

Conclusions

Clearly, recent forest management practices and those detailed in existing Forest Plans are not beneficial to Mexican spotted owls. Reliance on traditional forest management and silvicultural techniques may no longer be possible, not only with respect to the conservation of the Mexican spotted owl but also with respect to maintaining other ecosystem attributes. New approaches must be developed that ensure the long-term provision of owl habitat and the maintenance of ecosystem structure and function. Traditional approaches will still have their role, but perhaps used in slightly different ways and with different intensities. Innovative applications of uneven-aged management may be particularly useful in developing and maintaining spotted owl habitat. In addition, particular applications of uneven-aged management may be useful in maintaining habitat conditions for the owl where they exist. In some cases, the application of even-aged management systems may also be appropriate, so future forest management should not preclude the use of even-aged management.

GRAZING

Grazing by livestock and wildlife (e.g., elk, deer) occurs throughout the range of the Mexican spotted owl. Depending on the intensity, grazing has the potential to influence habitat composition and structure, and affect food availability and diversity for the owl. However, predicting the magnitude of grazing effects on spotted owls and their habitat, and evaluating management options requires a better understanding of the relationship between spotted owl habitat and grazing.

Specific studies that document the effects of livestock and wildlife grazing on spotted owl habitat have not been conducted. Until specific information is available, the potential effects on the owl of grazing and trampling of vegetation must be identified and considered to the extent possible. For example, livestock and wildlife may not impact spotted owl roost and nest sites immediately, but could alter riparian habitats by reducing, eliminating, or suppressing regeneration. In time, reduced regeneration could limit the development of overstory structure needed for nesting, roosting, and other life history needs, as well as jeopardize the sustainability of these habitat types.

Grazing can alter a plant community directly, indirectly, or both. Direct alterations may be as obvious as plant removal by consumption or as subtle as removal by trampling. Indirect alterations may be as straightforward as loss of seed source or as insidious as damaged soil (Dwyer et al. 1984, Kauffman and Krueger 1984, Fleischner 1994). Moderate to heavy grazing can reduce plant density, cover, biomass, vigor, and regeneration ability. Collectively, these factors can alter the relative composition and structure of grass, forb, shrub, and tree components in an area (Hanley and Page 1982, Zimmerman and Neuenschwander 1984, Schulz and Leininger 1990, Milchunas and Lauenroth 1993). Within conifer forests, grazing can remove or greatly reduce grasses and forbs, thereby allowing large numbers of conifer seedlings to become established because of reduced competition for water and nutrients and reduced allelopathy. Establishment of large numbers of seedlings coupled with the reduction in light ground fuels (i.e., grasses and forbs) may act synergistically with fire suppression to contribute to dense overstocking of ladder fuels. This dense overstocking can alter forest structure and composition and degrade spotted owl and prey habitats while increasing risks of stand-replacing fires.

Beyond the effects of grazing on plants, livestock activity can increase duff layers, accelerate decomposition of woody material, produce compacted soils, damage stream banks and channels, and damage lake shores (Kennedy 1977, Blackburn 1984, Kauffman and Krueger 1984, Skovlin 1984, Clary and Webster 1989). The combination of these changes to the biotic and physical landscapes also affects plant community composition, structure, and vigor. If such changes occur in or near areas used by spotted owls, then grazing can influence the owl. Those influences can be manifested by altering (1) prey availability, (2) susceptibility of spotted owl habitat to fire, (3) the health and condition of riparian communities; and (4) development of habitat. We summarize below the major suspected influences of grazing on Mexican spotted owls.

1. For the Mexican spotted owl, prey availability is determined by the distribution, abundance, and diversity of prey and by the owl's ability to capture it. Grazing may influence prey availability in dissimilar ways. For example, grazing that reduces dense grass cover can create favorable habitat conditions for deer mice while creating unfavorable conditions for voles, meadow jumping mice, and shrews (Medin and Clary 1990, Schultz and Leininger 1991). This change might decrease prey diversity (Medin and Clary 1990, Hobbs and Huenneke 1992). A diverse prey base can provide a more predictable food resource for the owls over time, because popula-

tions of many small mammals fluctuate asynchronously. Conversely, short-term removal of grass and shrub cover may improve conditions for the owl to detect and capture prey. Long-term loss of grasses, forbs, and shrubs may promote tree growth and cover that could decrease prey abundance. Thus, grazing can pose ecological tradeoffs.

2. Grazing that significantly reduces herbaceous ground cover and increases shrubs and small trees can decrease the potential for beneficial low-intensity ground fires while increasing the potential for destructive high-intensity vertical fires (Zimmerman and Neuenschwander 1984). Low-intensity ground fires prevent fuel accumulation, stimulate nutrient cycling, promote grasses and forbs, discourage shrubs and trees, and perpetuate the patchiness that supports small mammal diversity. Catastrophic fire reduces or eliminates foraging, wintering, dispersal, roosting, and nesting habitat components.

3. Excessive grazing in riparian areas can reduce or eliminate important shrub, tree, forb, and grass cover, all of which in some capacity support the owl or its prey. Excessive grazing can also physically damage stream channels and banks (Ames 1977, Kennedy 1977, Kauffman et al. 1983, Blackburn 1984, Slovkin 1984, Clary and Webster 1989, Platts 1990.) Deterioration of riparian vegetation structure can allow channel widening. This event, in turn, elevates water and soil temperatures and thus evaporation and lowering of water tables, plus it significantly increases the potential for accelerated flood damage (Platts 1990). These processes alter the microclimate and vegetative development of riparian areas, potentially impairing its use by spotted owls.

4. Excessive grazing, sustained for long periods, can inhibit or retard an area's ability to produce or eventually mature into habitat for the owl or its prey. This will probably prove to be an inevitable consequence of the events and processes described above.

The potential for grazing to influence various components of spotted owl habitat cannot be ignored. However, current predictions of grazing effects on plant communities as they relate to the owl are inexact. Thus, the integration of spotted owl needs and grazing management will require coordination, and an interactive and adaptive approach between protection, restoration, and management.

RECREATION

Recreational activities may affect Mexican spotted owls directly by disturbing nests, roosts, or foraging sites. Disturbance may occur indirectly through altered habitat caused by trampling of vegetation, soil damage, or both. Developing new recreation facilities or expanding existing facilities, such as campgrounds and trails, may alter spotted owl habitat and habitat use and perpetuate disturbance impacts caused by recreation.

If a given recreational activity does not cause habitat alteration, the Team assumes that that activity generally has relatively low impact potential with respect to spotted owls. However, exceptions may exist in local situations or certain RUs where the level of recreational activities is high. Essentially, the determining factor of an activity's impact on spotted owls is a combination of its location, intensity, frequency, and duration rather than simply its character.

Types of Recreation

Recreational activities fall into several categories; the number, size, and intensity of such activities will vary with location. The following general categories include most widespread recreational activities that might affect spotted owls and their habitat.

Camping

Although the effects of camping on spotted owls have not been studied, disruption of nesting, roosting, and foraging activities is a distinct possibility. The character of camping varies dramatically, however. One person may camp alone in a small tent, whereas others may camp in groups with motorhomes. The disparity in character does not necessarily translate to disturbance potential, however. One person camping in a nest grove could be more disruptive than 12 people camping in a foraging area. Therefore, blanket generalizations about the impacts of camping activities are inappropriate. These activities should be assessed on a case-by-case basis, considering factors such as the location of the activity relative to the owls, the number of individuals involved, the type of group involved, and the frequency and duration of the activity.

Hiking

Hiking is typically a short-term activity, and may bring a person into and out of an owl's presence relatively quickly. Most spotted owls appear to be relatively undisturbed by small groups (≤12 people) passing nearby. Larger groups are probably more disruptive, but the more serious threat of disturbance probably arises where there is steady hiking traffic. Popular trails through spotted owl habitat may attract enough hikers to disturb owls. Certain kinds of hiking activities may degrade portions of spotted owl habitat, disrupt crucial behaviors, increase susceptibility of owls to predation, or cause abandonment of a nest area or key roost grove. The potential for hikers to disturb owls is probably greatest where hiking is concentrated in narrow canyon bottoms occupied by nesting or roosting owls. Again, we argue that blanket statements about the effects of hikers on owls are inappropriate, and recommend evaluation on a case-by-case basis as described above.

Off-road Vehicles

Both motorized and nonmotorized vehicles may degrade or destroy spotted owl habitat, particularly meadow and shrub habitats vital to the owl's prey. Noise produced by vehicles and the vehicle riders may disturb spotted owls at important nesting and roosting sites.

Rock-climbing

In some portions of its range, the spotted owl nests and roosts in shallow recesses and caves associated with canyon walls and cliffs. Rock-climbing activities in the vicinity of cliff-dwelling spotted owls could disturb the owls, particularly during the nesting season. This problem could be partially alleviated by invoking seasonal closures in areas of conflict. Again, case-by-case evaluations of activities and their potential for disturbance seem most appropriate.

Wildlife Viewing and Photographing

Because birders and wildlife photographers actively seek spotted owls, their encounters may be more disruptive than the accidental encounters associated with other recreational activities. Such recreationists often make repeated visits and may follow birds that flush. They often employ hooting or mousing techniques to attract the owls, and these behaviors, practiced to excess, may disrupt owls' territorial, mating, and nesting activities.

Recreation Summary

Incidental encounters between spotted owls and people pursuing some recreational activity are relatively insignificant in most cases. In other cases, there may be significant effects. These are relatively uncommon, and are typically localized. Consequently, these situations will usually impact one or at most a few pairs of owls, and are not likely to impact large portions of the owl population. We believe that these situations are best evaluated on a case-by-case basis.

In a broader sense, the construction of recreation facilities, the loss of habitat to make room for recreation facilities, the collective effect of recreation traffic, and the compounding effects of recreation in concert with other site-specific disturbance factors make recreation management an important consideration for delisting.

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SUMMARY

Part III of this Recovery Plan outlines management guidelines to alleviate threats to the spotted owl. These recommendations are based largely upon the Team's evaluation of the biology of the owl as detailed in Volume II. From these analyses, the Team has drawn the following conclusions.

Mexican spotted owls generally occupy remnants of the landscape that have experienced minimal human disturbance. We acknowledge that exceptions to this generalization occur. These remnants include inaccessible canyons, steep slopes, wilderness, and other environments not heavily modified by humans. Persistence of owls depends partly on these remnant patches, but these environments alone may be insufficient to ensure long-term conservation of the Mexican spotted owl. A key point here is that not all human activies are detrimental to spotted owls. In fact, if directed appropriately, some human activities can be used to the owl's benefit. Consequently, management must focus on creating new habitat to replace remnants that become no longer appropriate for the owl. Creation of replacement habitat hinges on understanding patterns of natural variation and modifying human activities that might conflict with the development of habitat. Natural variation across the landscape results from unique biophysical conditions at each location on the land. Further, effects of human activities are equally variable across the landscape. Although we cannot ascribe strict cause-effect relationships of natural processes and human activities on Mexican spotted owls, we can draw certain inferences about their probable impacts. The previous section detailing the conceptual framework underlying the recovery measures provides the rationale for those inferences. Thus, the management recommendations (Part III) were based on two interrelated sets of information: (1) basic knowledge of Mexican spotted biology; and (2) understanding how various natural processes and human activities modify the environment to maintain, develop, and alter spotted owl habitat.

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Recovery

Volume I, Part III

A. DELISTING

Removing a species or subspecies from threatened status becomes a primary management objective the moment listing is finalized. Listing a species as threatened affords more protection to the species than it would normally receive through other laws governing wildlife. Specifically, "threatened" status implies that human activities and/or natural disturbances pose greater than normal risks to the entire species or subspecies rather than just to individuals. Greater protection can manifest itself as more explicit and careful regulation of human activities. In some measure, a Recovery Plan reconciles human needs and desires with the survival needs of the threatened species or subspecies. If successful, the reconciliation process leads to an arrangement to accommodate both people and the threatened species. Ultimately, careful regulation of human activities combines with careful management of natural resources to allow removing the species from threatened status, or "delisting." Just as listing a species requires a process of information gathering and assessment, delisting requires a similar process.

THE DELISTING PROCESS

Section 4 of the Act governs the listing, delisting, and reclassification of species, the designation of critical habitat, and recovery planning. Regulations implementing listing, delisting, reclassification, and critical habitat designation are codified at 50 CFR 424.

The process of delisting a species or subspecies is essentially the same as that of listing: a proposed rule describing the justification for the action is published in the *Federal Register*; a public comment period is opened, including public hearings if requested; and, within one year of the proposal, either a final rule delisting the species or a notice withdrawing the proposed rule is published in the *Federal Register*.

In considering whether to delist a species, the same five factors considered in the listing process (see Part I) are evaluated. While emphasis may be given to those factors leading to the species' listing, all of the factors must be evaluated in making a delisting determination.

Section 4(c)(2) of the Act directs the FWS to conduct, at least once every five years, a review of all listed species and determine for each species whether it should be removed from the list, reclassified from endangered to threatened, threatened to endangered, or remain in its current status. This Recovery Plan lists criteria only for delisting the Mexican spotted owl. Any decision to reclassify the subspecies to endangered status will be made by the FWS either as a result of the aforementioned mandatory review or at any other time information becomes available indicating that reclassification is appropriate.

Section 4(g) of the Act directs the FWS to implement a system in cooperation with the States to monitor effectively for not less than five years the status of a species or subspecies that has been delisted due to recovery. The provisions of the Act do not apply to the delisted species during this monitoring period. However, the FWS could relist a species, through the standard listing process, should monitoring indicate that the species will decline without the Act's protection.

DELISTING CRITERIA

We recognize that we lack data and authority to prescribe and implement monitoring strategies for Mexico. Thus, our recommendations below apply only to the U.S. range of the Mexican spotted owl. We recommend that Mexican authorities develop similar delisting criteria and monitoring schemes for delisting in Mexico.

Five specific criteria must be met before the Mexican spotted owl can be delisted in the U.S. The first three criteria, which operate at a multiple-RU level, must be satisfied before the last two criteria, which operate at the RU level, apply. These are the three overriding criteria:

1. The populations in the Upper Gila Mountains, Basin and Range - East, and

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Basin and Range - West RUs must be shown to be stable or increasing after 10 years of monitoring, using a study design with a power of 90% to detect a 20% decline with a Type I error rate (α) of 0.05.

2. Scientifically-valid habitat monitoring protocols are designed and implemented to verify that (a) gross changes in macrohabitat quantity across the U.S. range of the Mexican spotted owl are stable or increasing, and (b) microhabitat modifications and trajectories within treated stands meet the intent of the Recovery Plan.

3. A long-term, U.S.-rangewide management plan is in place to ensure appropriate management of the subspecies and adequate regulation of human activity over time.

Once these three criteria are satisfactorily achieved, delisting may occur in any U.S. RU that meets the final two criteria:

4. Threats to the Mexican spotted owl within the RU are sufficiently moderated and/or regulated.

5. Habitat of a quality to sustain persistent Mexican spotted owl populations is stable or increasing within the RU.

These criteria are, by design, redundant and dependent. Meeting one criterion, to some degree, requires meeting all or some portion of the other criteria. Integrating the criteria is unavoidable but nevertheless desirable. Progress on one translates to progress on all.

Monitoring Population Trends

For a statistically valid monitoring design, we suggest the quadrat sampling scheme described in III.C. The three RUs where population monitoring is required for delisting represent the bulk of the known Mexican spotted owl population in the U.S. No population delisting criteria are applied to the remaining U.S. RUs because they would be difficult to monitor because of the small, fragmented nature of the populations.

A premise for our population monitoring approach is that the *existing* Mexican spotted owl population in the U.S. is adequate. This premise will be tested by monitoring population trends. If the results of monitoring indicate that the U.S. population is stable or increasing over the next 10 to 15 years (assuming 10 years prior to delisting followed by the required 5 years after delisting), the Team is willing to accept that the current population will remain viable in the foreseeable future and to assume that the population is recovered. That is, the Team believes that if the current population is able to maintain itself, or to increase, then the population has exhibited evidence that it is of ample size to persist.

Our basis for the parameters included in the delisting criteria are as follows. The annual rate of change of the population within a RU can be estimated as $\lambda = \hat{N}_{t+1}/\hat{N}_t$. A population is stable if $\lambda = 1$, decreasing if $\lambda < 1$, and increasing if $\lambda > 1$. A 20% reduction over a 10-year period implies a value of $\lambda = 0.978$; i.e., $\lambda^{10} = 0.80$.

To conclude that a population is stable, we fail to reject the null hypothesis that $\lambda = 1$, or alternatively, that the 95% confidence interval on λ includes 1. If we fail to reject this null hypothesis, we want to ensure that the possible rate of decline is very small. Thus, we suggest a Type II error rate of 0.10, and for a 15-year period, the annual estimate of λ is $0.98523 = 0.8^{(1/15)}$.

For this statistical test of trend, continued persistence of the Mexican spotted owl population means the Type II error rate is more important than the Type I error rate. That is, a Type I error means that we mistakenly conclude that the population is declining when it is not. Although costly measures might be taken to reverse our incorrect perception of the trend in the owl population, the persistence of the population is not threatened. In contrast, a Type II error means that we conclude the population is stable or increasing when it is really declining. Thus, persistence of the population could be in jeopardy because measures would not be taken to correct the decline. Therefore, we emphasize that a low Type II error rate of $\beta = 0.10$ (power is $1 - \beta = 0.90$) must be met to delist the species.

Several biological reasons lead us to select a time span of 10-15 years for monitoring. The mean life span (MLS) of Mexican spotted owls that reach adulthood falls within this range. MLS is calculated as $1/(-\log(S))$, with *S* representing the adult survival rate. Using $S = 0.8889$ (SE = 0.0269), survival rates calculated from the demographic study areas, the MLS is about 8.5 years. Calculating confidence intervals for MLS yields 16.6 years as an upper age limit. Population turnover rates provide another biological argument for the time span (*x*) required for delisting. For example, we can estimate the time that it takes 90% of the youngest members of the adult population to completely turn over, or for 90% of the existing young adult birds to die. Given the adult *S* of 0.8889, solving for *x* in $0.8889^x = 1 - 0.90$ gives $x = 19.6$ years for 90% of a given cohort of young birds to turnover. A 50% turnover would be 5.9 years, which would correspond to the median life span. For *x* equals 10 years, 70% of the young adult population will have turned over.

The time duration for the monitoring and magnitude of change required to detect a population decline are related. Thomas (1990) argued that the minimum viable population size depended on the temporal variation expected in a population. Species with much temporal variation in their population size might normally exhibit a 20% decline over a short period. We do not expect Mexican spotted owl populations to display much temporal variation. The most variable aspect of their population biology is probably recruitment, and years of little or no recruitment may occur. However, because of the high adult survival rate, the decline in the population during a year of no recruitment would still only be 11%. Thus, two consecutive years of no recruitment would result in a 21% decline. But the fecundity estimates presented by White et al. (1995) suggest that no recruitment is unlikely. Thus, we conclude that a 20% decline over a 10-year period indicates the population is truly declining and is not the result of normal temporal variation.

The choice of a Type II error rate of 0.10 is somewhat arbitrary. However, this value interacts with the choice of a 20% decline over the 10-year period. Figure III.A.1 depicts a hypothetical curve for power as a function of the size of the effect being detected (labeled Detectable Effect Size in the graph). We could specify that a 15% change is detectable with a 67% power, or that a 25% change is detectable with a 94% power. These statements are all equivalent in terms of the effort required for the monitoring protocol (as shown by the graph). This is because the relationship between the detectable difference and the power to detect this difference is fixed by the monitoring effort (normally considered as the sample size of the statistical procedure). Thus, we have suggested that a 90% power to detect a 20% decline over 10 years is a reasonable point to fix the function that relates power and magnitude of the detectable effect.

In summary, we believe 10 years is a reasonable time span for monitoring because more than half of the adult population has turned over. Further, we expect that the population would have been subjected to adequate environmental variation during this 10-year period. Once the species is delisted, the additional five years of monitoring as required under the Act

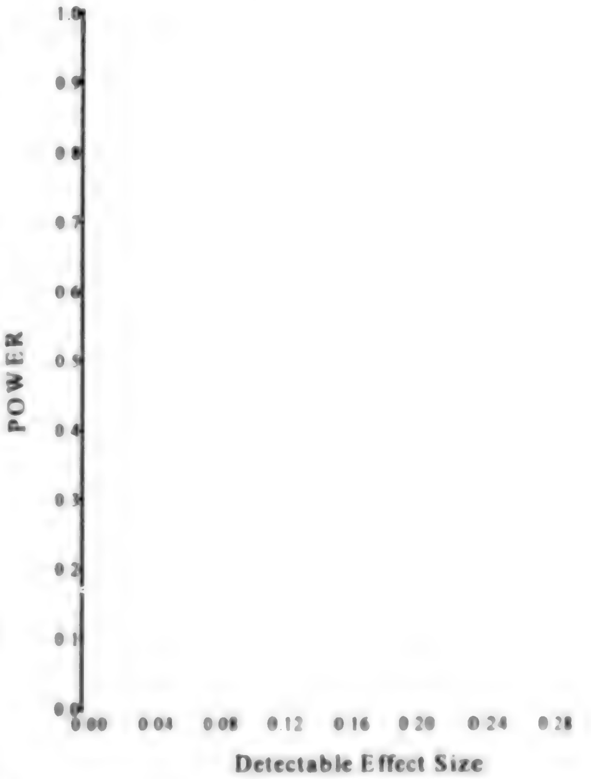

Figure III.A.1. Hypothetical curve of the statistical power to detect a trend in a population.

should provide further assurance that the population is not declining.

We believe that the delisting criterion proposed here provides positive incentives to land-management organizations to vigorously pursue the proposed population monitoring system. Delisting of the species depends on providing clearly specified evidence that the population is stable or increasing. The sooner the responsible land-management organizations begin the population monitoring, the sooner the owl can be delisted.

Other Considerations of Population Monitoring

The proposed procedure for population monitoring only monitors the territorial population of owls. Because nonterritorial owls ("floaters") do not respond to the usual methods of locating them (i.e., calling), the only method of monitoring nonterritorial birds is via radio-tracking. However, radio-tracking nonterritorial birds would require large samples of juveniles to be marked with radios, and these radios replaced on the birds as necessary to maintain the batteries as long as the individual remained in the nonterritorial population. Placing radios on spotted owls may alter their behavior and/or survival (Paton et al. 1991, Foster et al. 1992), making such an approach of questionable value. Thus, the Team concludes that no viable method of monitoring nonterritorial birds is available.

An alternative approach to monitoring populations was considered, that of using demographic study areas. We decided against using demographic studies for three reasons.

First, demographic study areas suffer from a deficiency that is not inherent in the quadrat place procedure described in III.C. Demographic study areas are chosen at the beginning of the monitoring period and must remain in place to provide appropriate data to meet their objectives. Because these study areas must be permanently delimited, management practices on them may not reflect those occurring on other lands. In contrast, quadrats can be randomly replaced in the sample to ensure that habitat changes and management practices adequately reflect those occurring on lands outside of the quadrats.

Second, the cost of demographic study areas probably exceeds the cost of our proposed quadrat monitoring approach. The cost of conducting five demographic studies for the California spotted owl is roughly equivalent to the estimated cost of quadrat monitoring (J. Verner, FS, PSW, Fresno, pers. comm). More than five demographic study areas would be needed for a valid population monitoring scheme, thus putting the cost of demographic study areas well above the costs of the proposed quadrat sampling procedure.

Finally, the two existing demographic study areas were not randomly selected from all possible demographic areas (thus not providing a defendable sample). Thus, results from the existing demography studies apply only to the place where these studies were done. Further, even if a demographic study approach was used, these existing study areas may not be included in the random sample needed for a statistically-defensible monitoring scheme.

The problems outlined above with respect to using demographic studies for monitoring do not negate the usefulness of such studies. Demographic studies were designed to understand aspects of spotted owl population biology and provide a wealth of information on populations, habitat characteristics, and parameters of owl fitness. They were not designed to monitor large-scale population trends.

Monitoring Habitat Trends

Ganey and Dick (1995) demonstrate that the Mexican spotted owl uses specific habitat characteristics. These features vary geographically, but within pine-oak and mixed-conifer forests spotted owls use areas that contain large trees, snags, high log volume, multistoried stand structure, and other specific attributes. Presently, habitat trends for the Mexican spotted owl are unknown, and the subject of conflicting speculation (II.D). Clearly, adequate habitat of sufficient quality must exist into the future to ensure population viability. Consequently, habitat monitoring is an essential part of the recovery

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process and the bird should not be delisted until monitoring can ensure unequivocally that sufficient habitat exists to support a viable population of spotted owls.

Habitat monitoring should address two aspects: persistence of forest types that owls prefer (macrohabitat) and specific habitat attributes within those types (microhabitat). This roughly corresponds to the coarse and fine filters described in II.D.

The first task, then, is to quantify large-scale changes in macrohabitat across the range of the bird. Given existing high fire risks and the current state of southwestern forests, we expect that net macrohabitat change over the next 10 years will be negative. Although some areas will develop into habitat as the result of succession and past management activities, the Team assumes that (1) most acreage currently on a trajectory to become habitat will not do so during the life of the plan, and (2) some habitat will be lost to fire during the next 10-15 years (II.D). Thus, the Team anticipates a slight decline in the total acreage of spotted owl macrohabitat during the short term. Unfortunately, we cannot specify *a priori* a threshold level of habitat loss that the spotted owl population can safely endure. That relationship can only be evaluated by combining the results of population and habitat monitoring.

The second task for habitat monitoring is to evaluate whether or not management prescriptions were implemented effectively, and whether treated stands will remain or become owl habitat in the near future. Prescriptions pertain primarily to the use of prescribed fire and various silvicultural tools. Monitoring to meet this objective would entail pre-treatment sampling to measure existing habitat attributes, and post-treatment sampling to verify that the prescription met the intent of the treatment. Attributes to be sampled include both those typically measured during stand examinations and also additional variables not typically measured but that are strong correlates of owl presence (e.g., canopy cover, log volume). The general design for measuring owl habitat can be modified to monitor other ecosystem attributes as well. That is, additional variables can be measured besides those needed for spotted owls as required for other ecosystem management objectives. These types of coordinated efforts will be crucial to meeting the monitoring needs inherent to both ecosystem and adaptive management.

Long-term Management Plan

As described in Part I, this Recovery Plan is intended to guide management for Mexican spotted owls over the next 10-15 years. If implemented as recommended, significant research will be conducted during this period and important new information will become available, specifically data on owl biology, population structure, and effects of certain management practices on owl habitat. Further, the guidelines that we propose for managing restricted areas (III.B) will provide a foundation upon which long-term management might be based. Evaluation of this approach and the information provided through research and monitoring will be integral to developing and refining a long-term plan for managing the Mexican spotted owl. Such a plan will be required before delisting can be considered.

Delisting at the RU Level

The Team recommends that once the population and habitat are shown to be stable or increasing, delisting should be considered at the RU level. When delisting is considered, attention must focus on the resolution of known threats and the identification of emerging threats that could potentially compromise population viability. Similarly, spotted owl habitat must be monitored in each RU to determine trends. Monitoring will reveal habitat decline, improvement, or relative stability. The reasoning is that if the threats are removed or adequately regulated and if habitat trends are stable or showing improvement, protection under the Act will no longer be necessary. Conversely, a habitat decline or a lack of adequate regulatory mechanisms (other than provided by the Act) would warrant continued protection under the Act.

The reasoning behind monitoring population levels within three RUs and habitat in all RUs is as follows. A viable core population will

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exist in the three RUs if the population is shown to be stable or increasing. Therefore, if habitat rangewide is also stable or increasing, the core population is provided the opportunity of expanding its area and greatly increasing the persistence probability of the subspecies. As discussed by Keitt et al. (1995), some key unoccupied habitat patches are potentially significant in the expansion of the core population.

Moderating and Regulating Threats

Threats to be moderated include those that need site-specific treatment to alleviate them. The primary threat throughout the forested U.S. range of the Mexican spotted owl is the threat of widescale, stand-replacing fire. For threats to be considered as moderated, reasonable progress must have been made in removing the threats and adequate assurance, in the form of the long-term management plan described above, must exist that those programs will continue as necessary.

Threats to be regulated include those resulting from agency management programs or other anthropogenic activities that are either ongoing or reasonably certain to occur. A partial listing of threats besides fire include:

1. Timber or fuelwood harvest that either directly affects habitat within a territory or indirectly affects the owl by collateral activity adjoining owl territories;
2. urban and rural land development;
3. livestock and wildlife grazing;
4. recreation involving both consumptive and nonconsumptive activities.

Habitat Trends Within Recovery Units

For the spotted owl to be delisted within any RU, the following conditions must be met. First, threats to the continued loss of habitat and key habitat components must be moderated and regulated as detailed in the previous section. Second, habitat trends must be monitored to assess gross changes in habitat quantity within each RU. Third, effects of modifying activities within existing and potential spotted owl habitat must be monitored to ensure that existing habitat is maintained and potential habitat is progressing towards becoming replacement habitat.

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B. GENERAL APPROACH

The Recovery Plan recommendations are a combination of (1) protection of both occupied habitats and unoccupied areas approaching characteristics of nesting habitat, and (2) implementation of ecosystem management within unoccupied but potential habitat. The goal is to protect conditions and structures used by spotted owls where they exist and to set other stands on a trajectory to grow into replacement nest habitat or to provide conditions for foraging and dispersal. By necessity this Plan is a hybrid approach because the status of the Mexican spotted owl as a threatened species requires some level of protection until the subspecies is delisted. These constraints modify ways and opportunities to manage ecosystems within landscapes where owls occur or might occur in the future. We are applying ecosystem management in two slightly different ways. Within unoccupied mixed-conifer and pine-oak forest on <40% slope, we provide both general (coarse filter) and specific (fine filter) guidelines to provide a sustainable quantity of replacement nest habitat across the landscape. Within other unoccupied forest and woodland types (e.g., ponderosa pine, spruce-fir, aspen, and pinyon-juniper), general guidance is provided for managing the landscape to meet multiple ecosystem management objectives including spotted owl foraging and dispersal habitat.

Management priority should focus on actions to alleviate threats to Mexican spotted owls; thereafter, or in coordination with alleviating threats, other management priorities (e.g., creating replacement owl habitat) should be pursued. Two primary threats that managers should focus on are catastrophic wildfire and the widespread use of even-aged silviculture.

Heavy accumulations of ground and ladder fuels have rendered many Southwestern forests vulnerable to stand-replacing fires. Such fires represent real and immediate threats to the existence of spotted owl habitat. The management guidelines that follow are intended to provide land managers with flexibility to reduce these fuel levels and abate fire risks. Fire management should be given the highest priority.

Even-aged silviculture within potential owl habitat is regarded as a threat because it tends to simplify stand structure and move stands away from containing structures used by owls. We recognize, however, that such regeneration cuts may provide useful tools in certain circumstances to manage for spotted owls and other ecosystem objectives. Any use of even-aged management should be done sparingly and only after careful deliberation to ensure that it represents the best approach to meet management objectives.

Under proposed delisting criteria the owl could be delisted within 10 years, rendering the protection measures in this Recovery Plan obsolete. At that time, we anticipate having sufficient knowledge to design a strategy for long-term conservation of the Mexican spotted owl. Many of the ecosystem management guidelines provided in this Plan will provide a foundation for development of the long-term strategy. In formulating our recommendations, we assume that population and habitat status will be monitored in conjunction with implementation of these management guidelines. This Recovery Plan is analogous to a three-legged stool (Figure III.B.1); therefore, the management guidelines are not meant to stand alone. Monitoring provides objective criteria to assess the efficacies of the management guidelines. Without both habitat and population monitoring, the status of the owl cannot be assessed and it should not be delisted. We further assume that existing management constraints on vegetative manipulations (such as size of openings and maintenance of hiding and thermal cover for other species) will remain in place. This assumption is especially critical for vegetation types--ponderosa pine, pinyon-juniper, aspen, and spruce-fir--for which we provide no specific management recommendations.

ASSUMPTIONS AND GUIDING PRINCIPLES

The recommendations proposed here are based on several key assumptions about habitat requirements of the Mexican spotted owl, and a

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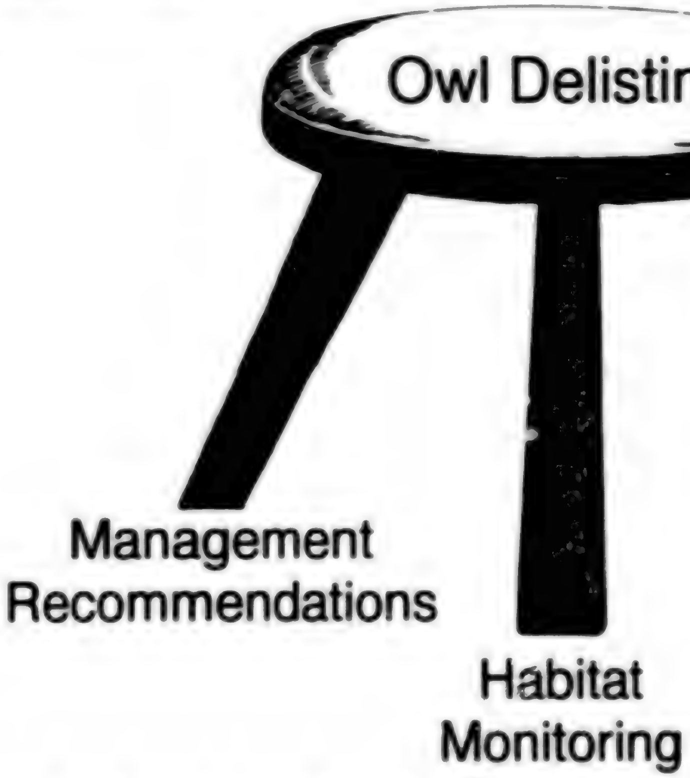
Figure III.B.1. Conceptualization of the Recovery Plan and needs for delisting of the Mexican spotted owl depicting the interdependency of population monitoring, habitat monitoring, and management recommendations.



number of guiding principles. These are enumerated below.

Assumptions

1. Spotted owl distribution is limited primarily by the availability of habitat types used for nesting and/or roosting.

2. Habitats used for nesting/roosting also provide adequate conditions for foraging and dispersal activities. Thus, providing nesting/roosting habitat partially meets other survival requirements as well. In turn, some stand structures not used for nesting/roosting may provide adequate conditions for other activities such as foraging and dispersal. These include some stands in younger seral stages than typical nesting/roosting habitat.

3. Nesting/roosting habitat in forest environments is typified by certain structural features, including large trees and late seral characteristics, which are common in, but not restricted to, old-growth forests.

4. Forested nesting/roosting habitat is typically found in mixed-conifer, pine-oak, and riparian forests. Other habitat types are used primarily for foraging, dispersal, or wintering. Thus, the distribution of nesting/roosting habitat is naturally discontinuous. Further, the potential distribution of such habitat is quite limited in some areas.

5. The presence of shade-intolerant species in many spotted owl nest/roost stands suggests that these areas are dynamic and have developed over time, often from more open stands. Disturbance events leading to forest canopy gaps may be important in maintaining shade-intolerant species, particularly in mixed-conifer stands.

6. Existing stand structures used by Mexican spotted owls for nesting/roosting generally have not been a target of planned silvicultural treatments. Where such conditions exist in managed stands, they are more than likely an unplanned

rather than purposeful result. The existence of Mexican spotted owl nesting/roosting habitat usually results from the lack of recent alteration of forest structures in certain landscapes.

Guiding Principles

1. Silvicultural applications must be evaluated over time by rigorous monitoring procedures to assess their effectiveness in managing or creating owl habitat.

2. Obtaining large trees is a function of both time and site productivity. Similarly, many late seral characteristics typical of owl habitat, such as broken-topped trees, snags, large downed logs and the sharing of growing space among multiple shade-tolerant and intolerant species, are attained primarily through time.

3. Although this Recovery Plan represents a short-term strategy, management actions recommended herein will have long-term consequences. Therefore, care should be taken to preserve future options while evaluating the effectiveness of proposed treatments.

GENERAL RECOMMENDATIONS

General management recommendations for use throughout the range of the Mexican spotted owl are given here. These general recommendations apply primarily to forested areas, and aspects of the recommendations are more applicable to some locations than others. Because the severity of potential threats varies among RUs, the general guidelines should be prioritized and applied accordingly. Specific management priorities are emphasized in sections on individual RUs, as warranted by the differences among RUs.

Three levels of habitat management are given in this Recovery Plan: protected areas, restricted areas, and other forest and woodland types (Figure III.B.2). Protected areas receive the highest level of protection under this plan, other forest and woodland types the lowest. Guidelines proposed in this Recovery Plan take precedence over other agency management guidelines in protected areas. Guidelines for restricted areas are less specific and operate in conjunction with ecosystem management and existing management guidelines. We propose no owl-specific guidelines for lands not included in protected and restricted areas; these areas will continue to be managed under existing guidelines, assuming that the emphasis is towards ecosystem management.

One guideline that applies to all areas with any potential for owl use is to inventory for spotted owls before implementing any management action that will alter habitat structure. If results of past inventory efforts can demonstrate unequivocally that no spotted owls have been detected within a given area or habitat and that the probability of detecting a bird there is small, then future surveys may not be needed. Under such circumstances, concurrence must be granted by the Recovery Team through the appropriate RU working team.

Protected Areas

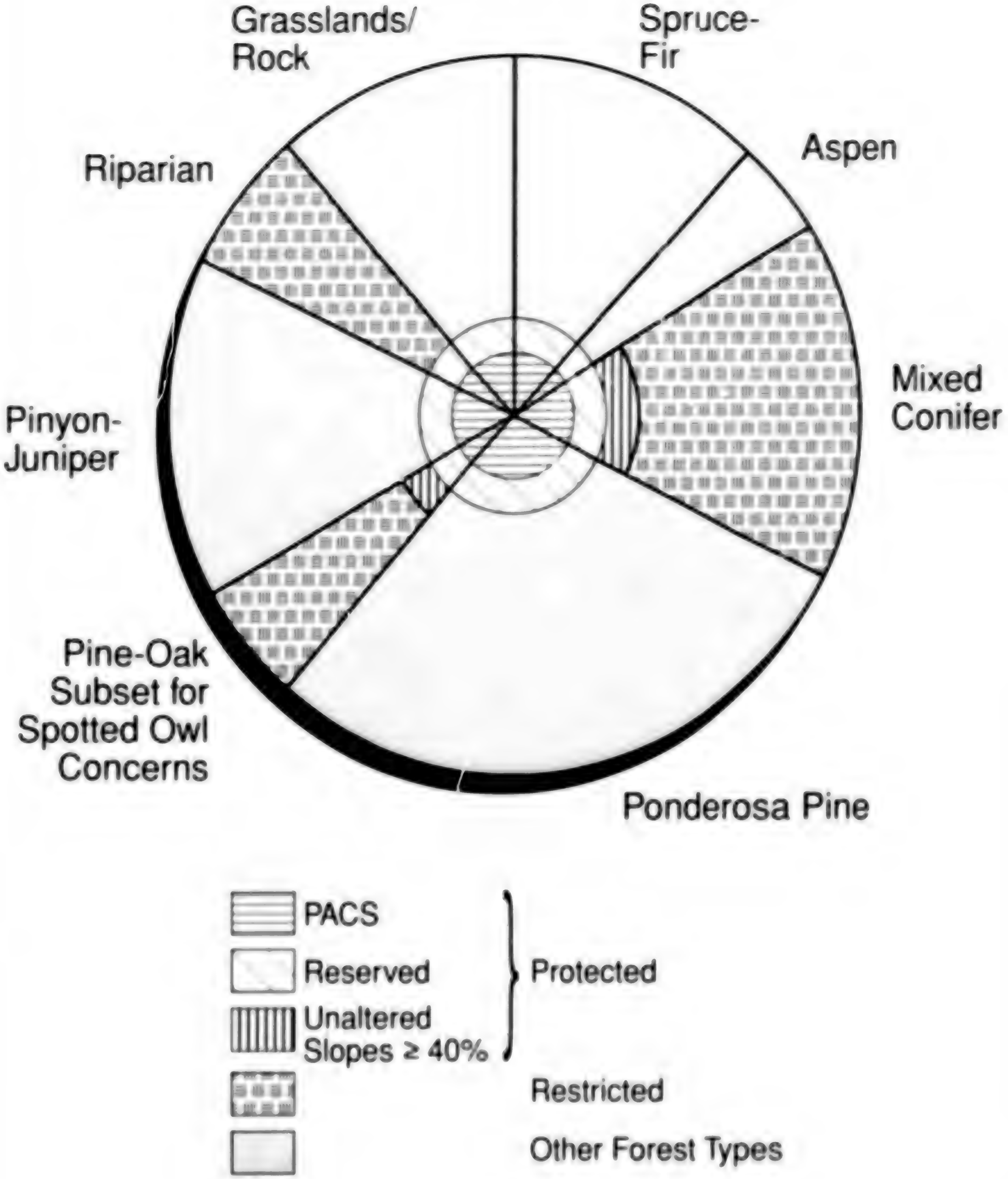
Protect all Mexican spotted owl sites known from 1989 through the life of the Recovery Plan (Protected Activity Centers), all areas in mixed-conifer and pine-oak types (defined in II.C) with slope >40% where timber harvest has not occurred in the past 20 years, and all legally and administratively reserved lands. Specific guidelines and the rationale for these guidelines are provided below.

Protected Activity Center (PAC)

Guidelines.—Eight specific guidelines pertain to the designation and implementation of PACs. These guidelines supersede steep slope guidelines; that is, steep slopes occurring within PACs should be managed under PAC guidelines.

1. Establish PACs at all Mexican spotted owl sites known from 1989 through the life of the Recovery Plan, including new sites located during surveys. PACs should also be established at any historical sites within the Colorado Plateau, Southern Rocky Mountains - Colorado, and

Figure III.B.2. Generalization of protection strategies by forest/vegetation type. Proportions are not to scale.



Southern Rocky Mountains - New Mexico RUs. Identify the activity center within each PAC. "Activity center" is defined as the nest site, a roost grove commonly used during the breeding season in absence of a verified nest site, or the best roosting/nesting habitat if both nesting and roosting information are lacking. Site identification should be based on the best judgement of a biologist familiar with the area. Delineate an area no less than 243 ha (600 ac) around this activity center using boundaries of known habitat polygons and/or topographic boundaries, such as ridgelines, as appropriate (Figure III.B.3). The boundary should enclose the best possible owl habitat, configured into as compact a unit as possible, with the nest or activity center located near the center. This should include as much roost/nest habitat as is reasonable, supplemented by foraging habitat where appropriate. For example, in a canyon containing mixed-conifer on north-facing slopes and ponderosa pine on south-facing slopes, it may be more desirable to include some of the south-facing slopes as foraging habitat than to attempt to include 243 ha (600 ac) of north-slope habitat. In many canyon situations, oval PACs may make more sense than, for example, circular PACs; but oval PACs could still include opposing canyon slopes as described above. All PACs should be retained for the life of this Recovery Plan, even if spotted owls are not located there in subsequent years. A potential exception to this rule is described in #8 below. Feedback on PAC delineation should be provided to managers through RU working groups (see Part IV). PAC boundaries may not overlap.

2. No harvest of trees >22.4 cm (9 in) dbh is allowed in PACs. Harvest of any trees is only permitted as it pertains to 5 below.

3. Fuelwood harvest within PACs should be managed in such a way as to minimize effects on the owl, its prey, and their habitats. The most effective management to meet these objectives may be to prohibit such harvest. However, we recognize that it may be virtually impossible to enforce such a prohibition and restrict access to all PACs for fuelwood harvest. When fuelwood harvest in PACs is unavoidable, we advocate the use of various forms of management that can regulate access to PACs and to the types of fuels harvested. Potential forms of fuelwood management include road closures, prohibiting harvest of important tree species such as oaks, prohibiting harvest of key habitat components such as snags and large downed logs (>30 cm [12 inch] midpoint diameter), and encouraging the harvest of small diameter conifers in accord with 5c below. Prohibiting fuelwood harvest of key habitat components such as oaks, snags, and large logs should be applied both inside and outside of PACs to ensure that these special components remain on the landscape.

4. Road or trail building in PACs should generally be avoided but may be allowed on a case-specific basis if pressing management reasons can be demonstrated.

5. Implement a program consisting of appropriate treatments to abate fire risk. The intent of this program is to assess the combined effects of thinning and fire on spotted owls and their habitat. The program should be structured as follows:

   a) Select up to 10% of the PACs within each RU that exhibit high fire risk conditions. Nest sites must be known within these PACs. Ideally, a paired sample of PACs should be selected to serve as control areas.

   b) Within each selected PAC, designate 40 ha (100 acres) centered around the nest site. This nest area should include habitat that resembles the structural

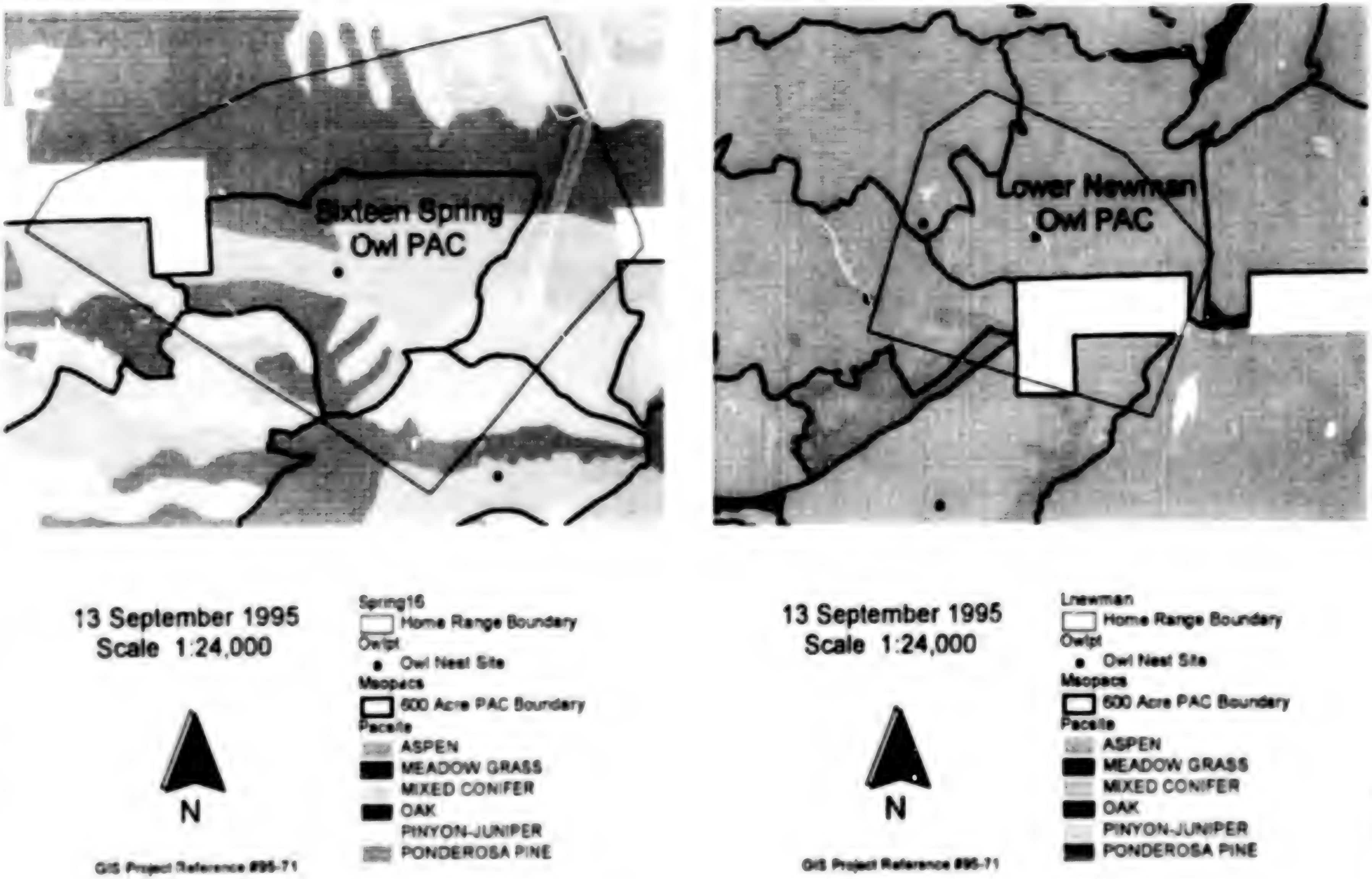


Figure III.B.3. Examples of protected activity center (PAC) boundaries from the Lincoln National Forest. Prepared by D. Salas and L. Cole, Lincoln NF.

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and floristic characteristics of the nest site. These 40 ha (100 acres) will be deferred from the treatments described below.

c) Within the remaining 203 ha (500 acres), combinations of thinning trees <22.4 cm (9 inches) dbh, treatment of fuels, and prescribed fire can be used to reduce fire hazard and to improve habitat conditions for owl prey. Habitat components that should be retained or enhanced include large logs (>30 cm [12 inches] midpoint diameter), grasses and forbs, and shrubs. These habitat components are strong correlates of the presence of many key prey species of the owl. Emphasis of the spatial configuration of treatments should be to mimic natural mosaic patterns.

d) Treatments can occur only during the nonbreeding season (1 September-28 February) to minimize any potential deleterious effects on the owl during the breeding season.

e) Following treatments to 10% of the PAC's, effects on the owl, prey species, and their habitats should be assessed. If such effects are non-negative, an additional sample of PAC's may be treated. If negative effects are detected, these effects must be carefully evaluated. If they can be ameliorated by modifying treatments, those modifications should occur prior to treatment of additional PAC's. If not, no additional treatments should be permitted.

6. Within the remaining PAC's, light burning of ground fuels may be allowed within the 500 acres surrounding the 100-acre PAC centers (5b above), following careful review by biologists and fuels management specialists on a case-specific basis. Burns should be designed and implemented to meet the objectives noted in 5c above. Burns should be done only during the nonbreeding season (1 September-28 February).

7. Within PAC'S treated to reduce fire risk, either by the use of prescribed fire alone or in conjunction with mechanical removal of stems and ground fuels, pre- and post-treatment assessments (i.e., monitoring) of habitat conditions and owl occupancy must be done. Specific habitat characteristics that should be monitored include fuel levels, canopy cover, snag basal area, volume of large logs (>30 cm [12 inch] midpoint diameter), and live tree basal area.

8. If a stand-replacing fire occurs within a PAC, timber salvage plans must be evaluated on a case-specific basis. In all cases, the PAC and a buffer extending 400 m from the PAC boundary must be surveyed for owls following the fire. A minimum of four visits, spaced at least one week apart, must be conducted before non-occupancy can be inferred. If the PAC is still occupied by owls or if owls are nearby (i.e., within 400 m of the PAC boundary), then the extent and severity of the fire should be assessed and reconfiguration of the PAC boundaries might be considered through section 7 consultation. If no owls are detected, then section 7 consultation should be used to evaluate the proposed salvage plans. If informal consultation cannot resolve the issue within 30 days, the appropriate RU working team should be brought into the negotiations.

Salvage logging within PAC's should be the exception rather than the rule. The Recovery Team advocates the general philosophy of Beschta et al. (1995) for the use of salvage logging. In particular: (1) no management activities should be undertaken that do not protect soil integrity; (2) actions should not be done that impede natural recovery of disturbed systems; and (3) salvage

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activities should maintain and enhance native species and natural recovery processes. Further, any salvage should leave residual snags and logs at levels and size distributions that emulate those following pre-settlement, stand-replacing fires. Scientific information applicable to local conditions should be the basis for determining those levels.

Rationale.—The primary objective to be achieved by these guidelines is to protect the best available habitat for the Mexican spotted owl, while maintaining sufficient flexibility for land managers to abate high fire risks and to improve habitat conditions for the owl and its prey. We assume that the best available owl habitat is that which is currently occupied by owls, or that occupied by owls in the recent past (since 1989). The median size of the adaptive kernel contour enclosing 75% of the foraging locations for 14 pairs of radio-marked owls was 241 ha (595 ac). Therefore, a 243 ha (600 ac) PAC should provide a reasonable amount of protected habitat and should provide for the nest site, several roost sites, and the most proximal and highly used foraging areas. We assume that existing management guidelines and those discussed below for areas outside of PACs will ensure the existence of additional habitat appropriate for foraging.

The intent of these guidelines is not to preserve these PACs forever, but rather to protect them until it can be demonstrated that we can create replacement habitat through active management. We describe below in the section covering restricted areas the approach for managing to create replacement habitat. Once land managers demonstrate that they can create replacement habitat, and when monitoring indicates that populations and habitats are stable or increasing, PACs could be abolished in conjunction with delisting the owl.

The Team recognizes that protection status carries some risk with respect to probabilities of catastrophic fire. The reason for the proposed management within PACs is to encourage a proactive approach to reduce fuel risks and simultaneously enhance prey habitat. If these objectives are achieved, existing owl habitat will be maintained and in some cases enhanced, while identified risks of catastrophic fire will be lessened.

Salvage logging in PACs should be allowed only if sound ecological justification is provided and if the proposed actions meet the intent of this Recovery Plan, specifically to protect existing habitat and accelerate the development of replacement habitat. Fires within PACs are not necessarily bad. In many cases, patchy fires will result in habitat heterogeneity and may benefit the owl and its prey. In such cases, adjustments to PAC boundaries are probably unnecessary and salvage should not be done. Salvage should be considered in PACs only when the fire is extensive in size and results in the mortality of a substantial proportion of trees.

Steep Slopes (outside of PACs)

Guidelines.—Within mixed-conifer and pine-oak types, allow no harvest of trees >22.4 cm (9 inches) on any slopes >40% where timber harvest has not occurred in the past 20 years. (Mixed-conifer and pine-oak types found on steep slopes that have been treated within the past 20 years are managed under restricted area guidelines below). These guidelines also apply to the bottoms of steep canyons. Thinning of trees <22.4 cm (9 inches) dbh, treatment of fuels, and fire are allowed, as discussed in 5c above. No seasonal restrictions apply, however. Prescribed natural fire is also permitted as is the creation of fire breaks on a case-specific basis.

On steep slopes treated to reduce fire risk, either by the use of prescribed fire alone or in conjunction with removal of stems and ground fuels, pre- and post-treatment monitoring of habitat conditions should be done. Specific habitat characteristics to be measured include fuel levels, snag basal area, volume of large logs (>30 cm midpoint diameter), and live tree basal area.

Rationale.—The objective of prohibiting timber harvest but allowing treatment of fuels and burning is to retain additional habitat with existing conditions similar to owl nesting/ roosting habitat while reducing fire risks. These

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conditions appear to be found commonly in mature/old-growth stands, and such stands are now found most commonly on steep slopes because past management practices have largely occurred on slopes <40%. We have restricted these guidelines only to the mixed-conifer and pine-oak types because existing information indicates that the owl favors these types for nesting and roosting (Ganey and Dick 1995).

These guidelines depart somewhat from recent management for steep slopes on southwestern FS lands. R. Fletcher (FS Southwestern Region, Albuquerque, NM, comment submitted on draft Recovery Plan) noted that only about 1,215 ha (3,000 acres) of steep slopes have been treated since 1987. Our guidelines emphasize that greater acreage should be treated through thinning and fire if threats of catastrophic fire are to be decreased on steep slopes. We have excepted steep slopes that been harvested in the recent past because many of these areas may not currently exhibit the forest structure spotted owls use for nesting or roosting. Guidelines for restricted areas apply to these lands.

Reserved Lands

Guidelines.—Encourage the use of prescribed natural fire where appropriate in Wilderness, Research Natural Areas, and other reserved lands.

Rationale.—Prescribed natural fire may be beneficial to owl habitat in several ways. First, it can aid in reducing fuel loads and risk of catastrophic wildfire resulting in loss of habitat over large areas. Second, it can create a diverse landscape with considerable horizontal heterogeneity. This seems to be relatively characteristic of many areas occupied by spotted owls and also provides for a diverse prey base. Third, it can create conditions that maintain shade-intolerant species such as ponderosa pine or Gambel oak in the landscape. Prescribed fires should be used carefully in spotted owl habitat, however; and the results should be monitored to evaluate the effects on habitat components suspected to be important to the spotted owl and its prey, such as large snags and logs.

Restricted Areas

Not all lands can or should receive equal protection. We provided guidelines above to protect all occupied nesting and roosting habitat, as well as unoccupied steep slopes and reserved lands. Potential exists, however, for the owl to use other, unoccupied areas. Thus, we provide additional guidelines to maintain and develop potential nesting and roosting habitat now and into the future. The guidelines that we present are stratified by broad vegetative cover types: mixed-conifer forest, pine-oak forest, and riparian areas. Definitions for pine-oak and mixed-conifer forests as applicable to these recovery measures are given in II.C.

For the most part, these guidelines apply to planning areas. Planning areas can be diversity units, sale planning areas, or ecological areas, all places where management activities are considered and evaluated. The intent is to spread activities over the landscape rather than concentrating them in particular areas. Management within restricted mixed-conifer and pine-oak forests is derived from concepts of ecosystem management. Ecosystem management, however, requires ecological assessments at hierarchies of spatial scales (Kaufmann et al. 1994:6). Thus, although management is applied to planning areas, it is crucial that the impacts are assessed at larger spatial scales (e.g., landscape, subregional, and regional scales).

The underlying objective of the following guidelines is to manage the landscape to maintain and create replacement owl habitat where appropriate, while providing a diversity of stand conditions and stand sizes across the landscape. As noted previously, we assume that the primary limiting factor for Mexican spotted owls is the amount of nesting habitat. A logical conclusion from this premise is that the landscape should be managed to sustain owl nesting habitat well distributed spatially. Because various natural processes lead to the development, maturation, and senescence of such stands through time, management should allocate stands in such a way as to mimic the natural landscape. We also assume that providing a continuous supply of nesting and roosting habitat requires that remaining stands be in various stages of ecological

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succession. The landscape mosaic resulting from such an allocation should ensure adequate nesting, roosting, and foraging habitat for the owl, and habitats for its variety of prey.

Existing Conditions

Ideally, assessments of existing conditions should follow the spatial hierarchy presented by Kaufmann et al. (1994:6). At the very least, existing distributions of seral stages should be assessed at the planning level, landscape, subregional, and regional scales (*sensu* Kaufmann et al. 1994). We recognize that information may be inadequate to conduct assessments at larger spatial scales, but this constraint should be ameliorated as resource agencies continue to acquire appropriate data. Existing vegetative conditions within mature-old stands must also be assessed to determine the treatment potentials within those stands. However, given the high frequency of recent stand-altering disturbances, many areas are likely deficient in mature to old-growth forests. Thus, any treatments to these stands should be applied judiciously, if at all.

Reference Conditions

Nesting and roosting target/threshold conditions.—Forested stands used by spotted owls have certain structural features in common. These conditions do not, nor can they, occur everywhere. For example, many south-facing slopes may never attain this type of forest structure. It is impossible for us to imagine every possible management scenario, and this limits our ability to formulate specific guidelines that would be appropriate to all situations. Our intent here is to protect appropriate nesting habitat structure where it exists and manage other stands to develop the needed structure.

Although our knowledge of spotted owl habitat is incomplete, nesting/roosting stands exhibit certain identifiable features, including high tree basal area, large trees, multi-storied canopy, high canopy cover, and decadence in the form of downed logs and snags (Ganey and Dick 1995). Further, these stands often contain a considerable hardwood component generally provided by Gambel oak in ponderosa pine-Gambel oak forests and by various species (e.g., oaks, maples, box elder, aspen) in mixed-conifer forests.

We used tree basal area, large tree (>45.7 cm [18 in] dbh) density, and tree size-class distribution as the variables to define target/threshold conditions (Table III.B.1). Other variables such as snags and downed logs are important as well. We assume that if the basal area and tree density levels given in Table III.B.1 exist, adequate amounts of snags and downed logs (and other habitat elements) should be present.

The values provided in Table III.B.1 represent targets in that they define the desired conditions to be achieved with time and management. They also represent threshold conditions in that they define minimal levels that must be maintained. That is, activities can occur within stands that exceed these conditions, but the outcome of such activities cannot lower the stands below the threshold levels unless large-scale ecosystem assessments demonstrate that such conditions occur in a surplus across the landscape (see below). Note that all values must be met simultaneously for a stand to meet target/threshold conditions.

We used two primary types of information to define target/threshold conditions. First, we used quantitative descriptions of site- and stand-level habitat conditions. Second, we estimated the proportion of the landscape that could sustain those conditions through time. A similar approach was provided for managing northern goshawk habitat in the southwest (Reynolds et al. 1992). Thus, our approach is not without precedence.

Despite repeated attempts by the Recovery Team to obtain data from land-management agencies and researchers, only limited data were available for our analyses. We used nest-site data collected by SWCA (1992) which included plot measurements centered (1) at each nest location, (2) a random location within each nest stand, and (3) a random location within a stand adjacent to the nest stand (see Ganey and Dick [1995] for more detailed information). We also used FS stand inventory data provided by the Coconino, Apache-Sitgreaves, and Lincoln National Forests. These data consisted of stand-level data stratified by nest, core, and territory stands. Core and territory delineations were

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Table III.B.1. Target/threshold conditions for mixed-conifer and pine-oak forests within restricted areas. Forest types are defined in II.C.

Recovery Units Forest type	% of area[1]	% stand density of trees 30.5-45.7 cm dbh (12-18 in)	% stand density of trees 45.7-61 cm dbh (18-24 in)	% stand density of trees >61 cm dbh (>24 in)	Tree basal area[2]	Density of large trees[3]
Basin and Range - East RU						
Mixed-conifer	20	10	10	10	32 (150)	49 (20)
Mixed-conifer	10	10	10	10	39 (170)	49 (20)
All RUs, except Basin and Range - East RU						
Mixed-conifer	25	10	10	10	32 (150)	49 (20)
Mixed-conifer	10	10	10	10	39 (170)	49 (20)
Colorado Plateau, Upper Gila Mountains, Basin and Range - West RUs						
Pine-oak[4]	10	15	15	15	32 (150)	49 (20)

[1] % of area pertains to the percent of the planning area, landscape, subregion, and region that must meet target/threshold conditions. For mixed-conifer forests within Basin and Range - East and then for all other RU's, the percentage figure on the second line is a subset of the percentage figure given immediately above.

[2] Basal area is m^2/ha (ft^2/acre).

[3] Trees >45.7 cm (18 inches) dbh. Density is trees/ha (trees/acre).

[4] For pine-oak, 4.6 m^2/ha (20 ft^2/acre) of oak must be provided as a threshold/target condition.

based on FS management guidelines for the Mexican spotted owl provided by ID No. 2 (see Part I). We had no way to assess the accuracy of the data. Different methods were used to collect the SWCA data from those used to collect the FS data, thus direct comparisons are tenuous. Neither data set was collected specifically to address our objectives; thus, the data were less than optimal for our purposes. Further, numerous people collected data and we cannot assess inter-observer variation (Block et al. 1987). As obvious as these points may be, they greatly limited the inferences that we could make based on our analyses. Thus, we relied on our best professional judgement to evaluate the analyses and formulate our recommendations.

We explored several analyses to derive target/threshold conditions including empirical univariate and multivariate analyses, and modeling. Most analyses converged on a set a values that were validated by existing data on spotted owl nesting habitat.

We used the following approach. First, we used the SWCA (1992) data to characterize nest stands on the basis of tree basal area, density of large trees, and the distribution of stand density by size classes. Next, we used the available FS stand data to identify the percentage of the contemporary landscape that simultaneously meets these values. Third, we modeled forest stands under various post-disturbance/stand initiation conditions using the Forest Vegetation Simulator (Wykoff et al. 1982, Dixon 1991, Edminster et al. 1991). This model allowed us to predict the amount of time that a stand would be in each successional stage, including the amount of time the stand would retain or exceed the characteristics required for nesting and roosting. Knowledge of how long a stand meets or exceeds target conditions was used to estimate the proportion of the landscape that should meet or exceed these stand conditions at a given time.

Analyses were conducted separately for mixed-conifer and pine-oak forests. We also provide two sets of values for mixed-conifer forest that reflect different target/threshold values which are applied to different proportions of the landscape (Table III.B.1). We reiterate that all target/threshold values must be met simultaneously. For example, within mixed-conifer forests in all RUs except Basin and Range - East, 25% of the landscape should consist of stands that have >32 m^2/ha (150 ft^2/acre) of tree basal area, and include >49 trees/ha (20 trees/acre) that are >45.7 cm (18 inches) dbh. Management should strive for an even distribution of stand density across all sizes classes with no less than 10% of the distribution of stand density in each of the upper three size classes: 30.5-45.7 cm (12-18 inches), 45.7-61.0 cm (18-24 inches), and >61.0 cm (24 inches). Also, 10% of the total landscape (a subset contained within the 25% discussed above), should have >39 m^2/ha (170 ft^2/acre) of basal area in addition to the large trees and distribution of trees by size class. Target/threshold conditions for mixed-conifer forests in the Basin and Range - East RU differ slightly in that landscape percentages are 20% and 10%. The areal percentage for Basin and Range - East RU is lower (20% compared to 25%) because of the high density of owls in the Sacramento Mountains which effectively places a large proportion of the landscape in protected status. Target/threshold conditions apply to only 10% of the pine-oak forest (Table III.B.1). Target/threshold conditions for pine-oak forests also require that >4.6 m^2/ha (20 ft^2/acre) of oak basal area be present, and that all oaks >13 cm [5 inches] dbh be retained (Table III.B.1).

Coarse Filter

We recognize that most project planning occurs at limited spatial scales such as 4,050 ha (10,000 acre) blocks. This limited spatial scale precludes ecological assessments at larger scales. Because of this limitation, the areal percentages provided in Table III.B.1 should be regarded as minimum levels for a given planning area. If a deficit occurs within the planning area, additional stands should be identified that (1) have the site potential to reach target conditions and (2) whose current conditions most closely approach those conditions. Those stands should then be managed to achieve target conditions as rapidly as possible. However, if the proportion of the planning area that meets target conditions is greater than the percentages in Table III.B.1, none of those stands can be lowered below threshold conditions until ecosystem assessments at larger spatial scales (landscape, subregion,

region) demonstrate that target conditions exceed the required areal percentages (Table III.B.1) at these larger scales. This does not preclude use of treatments to reduce fire risks or lessen insect or disease problems nor does it preclude management to meet other ecosystem objectives as long as stand-level conditions remain at or above the threshold values given in Table III.B.1.

Fine Filter

Overriding Guidelines.—Management activities that influence the owl and its habitat should be conducted according to the following overriding guidelines:

1. Manage mixed-conifer and pine-oak forest types to provide continuous replacement nest habitat over space and time. Treatment of a particular stand depends on its capability to attain the desired stand conditions. Target stand structure would be the described conditions for nesting and roosting habitat (Table III.B.1) but only the portion of the landscape that can be sustained through time should be in that condition.
2. Incorporate natural variation, such as irregular tree spacing and various stand/patch sizes, into management prescriptions and attempt to mimic natural disturbance patterns.
3. Maintain all species of native vegetation in the landscape, including early seral species. To allow for variation in existing stand structures and provide species diversity, both uneven-aged and even-aged systems may be used as appropriate.
4. Allow natural canopy gap processes to occur, thus producing horizontal variation in stand structure.

Specific Guidelines—The following guidelines are intended to minimize threats to the Mexican spotted owl, retain and enhance important but difficult-to-replace habitat elements, and provide management flexibility.

1. Emphasis should be placed on uneven-aged management systems. Existing stand conditions will determine which silvicultural system is appropriate.
2. Extend rotation ages for even-aged stands to >200 years. Silvicultural prescriptions should explicitly state when vegetative manipulation will cease until rotation age is reached. This age may depend on site quality, but ceasing activity at 140 years and allowing 60 years for unaltered stand maturation and senescence seems reasonable.
3. Within pine-oak types, emphasis should be placed on management that retains existing large oaks and promotes the growth of additional large oaks.
4. Retain all trees >61 cm (24 in) dbh.
5. Retain hardwoods, large down logs, large trees, and snags.
6. Management priority should be placed on reducing identified risks to spotted owl habitat. The primary existing threat is catastrophic wildfire. Thus, we strongly encourage the use of prescribed and prescribed natural fire to reduce hazardous fuel accumulations. Thinning from below may be desirable or necessary before burning to reduce ladder fuels and the risk of crown fire. Such thinning must emphasize irregular tree spacing.
7. No stand that meets threshold conditions can be treated in such a way as to lower that stand below those conditions until ecosystem assessments can document that a surplus of these stands exist at larger landscape levels (e.g., no less than the size of a FS District). This does not preclude use of treatments to reduce fire risks or lessen insect or disease problems, nor does it preclude management to meet other ecosystem objectives as long as stand-level conditions remain at or above the threshold values given in Table III.B.1.

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Rationale.—The collective goal of these general and specific guidelines is to provide spotted owl habitat that is well distributed over space and time. To accomplish this goal requires maintaining or creating stand structures typical of nesting and roosting habitats and sustaining them in sufficient amounts and distribution to support a healthy population of Mexican spotted owls. A few guidelines merit further comment.

Retaining large trees is desirable because they are impossible to replace quickly and because they are common features of nesting and roosting habitats for the owl. Fire, viewed as a natural formative process rather than as a destructive anthropogenic process, can be used advantageously to maintain or improve spotted owl habitat.

The guidelines presented above should not be misconstrued as onetime management events. For example, large trees and snags are required by the spotted owl and will continue to be needed by the owl in the future. Further, the approach outlined above provides a foundation for the development of a long-term management strategy. Once the owl is delisted, we expect that this general template can be evaluated, fine-tuned, and possibly applied to PACs and steep slopes.

Riparian Communities

Guidelines.—The goals of these guidelines are to maintain healthy riparian ecosystems where they exist and initiate restoration measures to return degraded areas to healthy conditions.

1. Maintain riparian broad-leaved forests in a healthy condition where they occur, especially in canyon-bottom situations. Where such forests are not regenerating adequately, active management may be necessary. Possible actions to restore these forests may include reducing grazing pressure, establishing riparian exclosures to manage forage use better, and shifting to winter grazing seasons.

2. Restore lowland riparian areas. Spotted owls once nested in riparian gallery forests. Conceivably, restored riparian forests could contribute additional nesting habitat in the future and could also create a landscape that is more effectively connected for dispersing owls.

3. Emphasize a mix of size and age classes of trees. The mix should include large mature trees, vertical diversity, and other structural and floristic characteristics that typify natural riparian conditions.

Rationale.—We assume that riparian forests provide important habitat for spotted owls. Many riparian systems within the range of the Mexican spotted owl are extremely degraded as the result of past management practices. Because many of these systems are degraded and little documentation of recent owl use exists, we have little empirical information upon which to provide specific guidelines. Thus, our underlying premise is that if riparian systems are restored to more natural conditions, the needs of the owl (and numerous other species) will be satisfied. This is particularly true in canyon-bottom situations at middle and lower elevations where little other typical nesting or roosting habitat may be available. We know that canyon bottoms are used extensively by the owl, thus it is important to preserve and increase the quality of such habitat. We anticipate that PACs will include some of the best of this type of habitat that still exists, but increasing the quantity and distribution of healthy riparian habitats provides the potential for increasing spotted owl habitat. Furthermore, maintenance of existing healthy riparian systems and restoration of those that are degraded will benefit numerous riparian-dependent flora and fauna, and ecosystem health across the landscape.

Other Forest and Woodland Types

We propose no specific guidelines for several forest and woodland community types where they occur outside PACs. These include ponderosa pine, spruce-fir, pinyon-juniper, and aspen as defined in II.C. We emphasize, however, that the lack of specific management guidelines within this plan does not imply that we regard these types as unimportant to the Mexican spotted owl.

The Team's rationale for these recommendations is based on extant information on the natural history of the Mexican spotted owl as summarized in Part II.A and detailed in Volume II. These forests and woodlands are not typically used for nesting and roosting. However, they may provide habitat for foraging and possibly for both dispersing and wintering spotted owls. Our grasp of the owl's natural history regarding these behaviors is incomplete, so we do not fully understand the structural features the owl requires for pursuing these activities in these forest and woodland types. Furthermore, some of the best foraging habitat should be protected in PACs. All of these circumstances allow us to be less restrictive in these community types without harming the owl or compromising its primary habitat.

With the exception of the acreage of these types contained within PACs, we assume that the remaining lands are used primarily for foraging, wintering, migration, and dispersal. Thus, we contend that existing and planned management for these types will maintain or improve habitat for these needs of the owl. This contention is based largely on the assumption that existing old-growth areas will be maintained across the landscape, silvicultural practices will favor selection over regeneration cuts, and management will be guided by ecosystem approaches that strive to provide sustainable conditions across the landscape that fall within the natural range of variation.

Guidelines developed for protected and restricted areas may have useful applications when judiciously administered in these other forest and woodland types. Such guidelines include managing for landscape diversity, mimicking natural disturbance patterns, incorporating natural variation in stand conditions, retaining special features such as snags and large trees, and utilizing fires as appropriate. We also emphasize the need for proactive fuels management where appropriate. Decreasing fire risks within these types, particularly ponderosa pine forests, will also decrease fire risks to adjoining protected and restricted areas by minimizing the probability of large landscape-level crown fires that could impinge upon occupied or potential nesting habitat.

GRAZING RECOMMENDATIONS

The explicit goals of managing grazing in spotted owl habitat reflect the four manifested influences of grazing discussed in II.D. Those influences were (1) altered prey availability, (2) altered susceptibility to fire, (3) degeneration of riparian plant communities, and (4) impaired ability of plant communities to develop into spotted owl habitat. The goals then become (1) to maintain or enhance prey availability, (2) to maintain potential for beneficial ground fires while inhibiting potential for destructive stand-replacing fire, (3) to promote natural and healthy riparian plant communities, and (4) to preserve the processes that ultimately develop spotted owl habitat.

The Team strongly advocates field monitoring and experimental research related to the impacts of grazing on the Mexican spotted owl. Only through monitoring and research can we (1) develop a comprehensive understanding of how grazing affects the habitat of the owl and its prey; (2) determine the effectiveness of current grazing standards and guidelines as they relate to the owl's needs; and (3) devise grazing strategies that can benefit the owl and its prey.

Grazing Guidelines

The following guidelines should be applied to all protected and restricted areas:

1. Monitor grazing use by livestock and wildlife in "key grazing areas." Key grazing areas are primarily riparian areas, meadows, and oak types. Monitoring should begin by determining current levels of use plus current composition, density, and vigor of the plants. Ultimately, monitoring should detect any change in the relative composition of herbaceous and woody plants. The intent is to maintain good to excellent range conditions in key areas while accommodating the needs of the owl and its prey.

2. Implement and enforce grazing utilization standards that would attain good to excellent range conditions within the key grazing areas. Use standards (e.g., FS Region 3, Range Analysis Handbook) that have been developed for local geographic areas and habitat types--particularly in key habitats such as riparian areas, meadows, and oak types--that incorporate allowable use levels based on current range condition, key species, and the type of grazing system. Establish maximum allowable use levels that are conservative and that will expedite attaining and maintaining good to excellent range conditions. The purpose of establishing these use levels is to ensure allowable use of plant species to maintain plant diversity, density, vigor, and regeneration over time. Additionally, a primary purpose is to maintain or restore adequate levels of residual plant cover, fruits, seeds, and regeneration to provide for the needs of prey species and development of future owl foraging and dispersal habitat.

3. Implement management strategies that will restore good conditions to degraded riparian communities as soon as possible. Strategies may include reductions in grazing levels and increased numbers of exclosures (i.e., fencing) to protect riparian plant cover and regeneration, and to prevent damage to stream banks and channels (Clary and Webster 1989, Platts 1990). In many cases, degraded riparian areas may require complete rest for periods from a few years to 15 years for the area to recover (Kennedy 1977, Rickard and Cushing 1982, Clary and Webster 1989). Additional strategies may include the use of riparian pastures, limited winter use, double rest-rotation, and other methods that emphasize riparian vegetation and stream bank/channel recovery (Platts 1990). Riparian restoration projects that include the use of exclosures need not require exclosures along the entire drainage course at one time. Rather, systematic use of exclosures that protect the most sensitive portions of riparian habitats is encouraged. Riparian areas can also benefit from protection of adjacent upland areas (Bryant 1982). Placement of exclosures (controls) and areas open to grazing (treatments) should be designed to permit determination of effects on several ecological responses (e.g., vegetation, erosion, water quality, prey availability).

Rationale for Grazing Guidelines

Some effects of excessive grazing on vegetation and habitat features are predictably negative, particularly in riparian communities. However, the collective effects of grazing are neither always predictable nor always negative. Effects depend on site-specific factors such as the grazing system, condition of the plant community prior to livestock grazing, soil types, climate, community composition of plant species, and the presence or absence of aggressive exotic plant species. Succinctly, predictability is inexact; and without predictability the Team cannot give detailed and specific recommendations.

We suggest that, when implemented and enforced, general guidelines and the standards they prescribe will promote and maintain good to excellent range conditions over time and across communities used by the owl. Despite our imprecise knowledge of how grazing affects spotted owl habitat, the collective body of general knowledge regarding the impacts of grazing on wildlife mandates prudence. The Team believes that understanding how grazing affects the owl is paramount, and we strongly urge that specific grazing practices and levels of grazing use be carefully evaluated through an experimental approach (Bock et al. 1993).

Habitats in protected and restricted areas should receive high-priority management attention relative to grazing. Any riparian communities of potential importance for spotted owl dispersal and wintering habitat should also receive high-priority attention. Such attention will not only benefit spotted owls but many other species in the Southwest as well (Hubbard

1977). Fundamental to the guidelines for grazing is the assumption that individual actions have collective effects. For example, the short-term goal of exclusion by fencing is to protect riparian plants and to prevent physical damage to stream banks and channels (Clary and Webster 1989, Platts 1990). The long-term goal is that such short-term protection ultimately allows spotted owl habitat to develop. Implicit in this rationale is that excessive grazing sustained for long periods not only deteriorates potential or actual spotted owl habitat but it also inevitably leads to a deterioration of the very qualities that make an area attractive for grazing in the first place.

We also assert that attainment and maintenance of good to excellent conditions in key grazing areas will translate to better conditions in the uplands. Most native and exotic ungulates preferentially graze within key areas such as meadows and riparian areas. We assume that if these key areas exhibit ecologically good conditions, upland forests and woodlands should also be in good condition. Thus, negative effects of grazing that lead to the establishment of ladder fuels and "dog-hair" thickets may be ameliorated.

RECREATION RECOMMENDATIONS

Guidelines

The following guidelines should be applied to all protected and restricted areas:

1. No construction, either of new facilities or for expanding existing facilities, should take place within PACs during the breeding season, 1 March through 31 August. Any construction within PACs during the nonbreeding season should be considered on a case-specific basis. Modifications to existing facilities pertaining to public safety and routine maintenance are excepted.

2. Managers should, on a case-specific basis, assess the presence and intensity of allowable recreational activities within PACs. Spatial and temporal restrictions should be considered for new activities.

3. Seasonal closures of specifically designated recreational activities should be considered where appropriate.

RECOVERY UNIT CONSIDERATIONS

We review below primary threats within each recovery unit. Some threats are ubiquitous across the range of the spotted owl, whereas others are limited to one or few RUs. To place these threats in perspective, we review below relevant information from Part II.B for each RU. Management priorities within each RU should focus on the threats identified below.

One management consideration that applies to all RUs is the potential for migration and dispersal of spotted owls within and among RUs. Admittedly, we know very little of the prevalence of such movements, nor do we know much of the habitats used. We suspect, however, that movements of birds may be important to gene flow and the maintenance of a metapopulation structure (Keitt et al. 1995). Thus, efforts should be made to preserve options by maintaining and enhancing potential avenues for migration and dispersal. This could be particularly important in specific canyons, riparian areas, and mountain ranges that might provide links within, between, and among RUs.

Colorado Plateau

The Colorado Plateau is the largest of all U.S. RUs. It encompasses the southern half of Utah, much of northern Arizona, most of northwestern New Mexico, and a small portion of southwestern Colorado. In the northwestern portion of this RU, owls have been located in steep-walled canyons with apparent concentrations in the areas of Zion N.P., Capitol Reef N.P., western Abajo Mountains, and Canyonlands N.P. Historical records are available from forested habitats on the Kaibab Plateau of northern Arizona. In the southeastern portion of this RU, owls occur in both steep-sloped, mixed-conifer forested canyons and steep-walled canyons on the Navajo Indian Reservation; known concentrations occur in the Black Mesa area and the Chuska Mountains. Owls have also been located in mixed-conifer habitats in the Zuni Mountains and on Mount Taylor (Figure II.B.3).

Owl distribution in this RU appears to be highly fragmented. This distributional pattern may be natural or the result of inadequate survey effort in some parts of the RU. Extensive surveys have, however, been completed in the southern Utah portion of this RU. Here, breeding owls have been found only in canyons where they nest and roost in caves and on ledges. In southern Utah, no breeding owls have been located in hundreds of thousands of hectares surveyed in mixed-conifer or other forest types in areas with less than 40% slope. Therefore, we recommend that surveys in southern Utah emphasize steep slopes and rocky canyons.

Potential Threats

Levels of recreational activity are high and increasing in some areas of this RU, such as southern Utah. Some activities may potentially lead to habitat alteration or direct disturbance of owls. Furthermore, owls in southern Utah nest and roost in canyons, and the physical structure of canyons tend to magnify disturbances and limit escape/avoidance routes for owls. Potential threats listed in order of severity for the northwestern portion of this RU include recreation, overgrazing, and road development within canyons, and catastrophic fire and timber harvest within upland forests potentially used for foraging, dispersal, and wintering. For the southeastern portion, threats include timber harvest, overgrazing, catastrophic fire, oil, gas, and mining development, and recreation (Utah Mexican Spotted Owl Technical Team 1994).

Southern Rocky Mountains - Colorado

Lying completely within the State of Colorado, the Southern Rocky Mountains - Colorado represents the northeastern extreme of the Mexican spotted owl's range. Few owls have been detected in this portion of its range, and its natural history in Colorado is poorly understood. However, the condition of a species being scarce at the periphery of its range is not unusual. Nesting and roosting habitat may be primary concerns, but wintering habitat may be an important factor in this RU. Although very little is known about wintering habitat, some data suggest that birds may winter at lower elevations that include a wider range of conditions than found in breeding habitats.

Potential Threats

In order of severity, potential threats for the Southern Rocky Mountains - Colorado RU are catastrophic fire, recreation, urbanization, timber harvest, and road construction. Less severe threats include land exchange, oil and gas leasing, mineral development, and grazing. Singly, these factors may have low impact, but high synergistic consequences. For example, much of the urban development in Southern Rocky Mountains - Colorado currently occurs at elevations lower than those occupied by breeding owls; but development increases recreational access to public lands. Road construction or expansion causes initial disturbance, recreation facilities extend the disturbance, and the improved access increases the contact between people and spotted owls. The initial activity may directly affect wintering habitat. The development threat is considered to be of low to moderate severity and is highest along the Front Range.

Southern Rocky Mountains - New Mexico

Ranking as the smallest U.S. RU, the Southern Rocky Mountains - New Mexico supports one of the smallest known populations of Mexican spotted owls as well. Existing data are too incomplete to cite even a crude estimate of the RU's spotted owl population or its density.

The inability to provide crude population estimates may be partially related to the inadequacy of existing survey protocols. Owl survey crews, following the FS Region 3 survey protocol, have speculated that spotted owls in the area may not respond to calling surveys as predictably as they do in other RUs. They base this opinion on the lack of response to nighttime calling in areas where owls or young have been observed during subsequent daytime visits. Given that surveys are an important step in designating PACs and the types of management permissible, it is critical that surveys have a high probability of detecting owls. Further, an ineffective, or partially effective, survey protocol leaves the FS and other agencies ill-equipped to manage potential threats to the Mexican spotted owl in the RU.

Recent survey efforts on the Santa Fe National Forest suggest that some areas formerly occupied by owls appear vacant now despite the fact that the habitat has not been altered appreciably (T. Johnson, Las Alamos, NM, pers. comm.). This perceived, but unconfirmed, population decline indicates the importance of protecting unoccupied habitat.

Potential Threats

The most serious threat to spotted owls in Southern Rocky Mountains - New Mexico RU is wildfire and, in localized areas, timber harvest. Fire may not be as serious in canyon systems as it is in other areas because the open structure of steep-slope woodlands associated with canyons are not conducive to conflagration. However, dense mixed-conifer and ponderosa pine forests outside of canyons may present the greatest fire hazards. Although these areas may not contain owls, fires initiated in these forests may continue into the forested canyon habitats. Personnel at Santa Fe National Forest have instituted an aggressive prescribed fire program in the Jemez Mountains as a way to reduce the risk of extensive fire. Though useful, prescribed fire should be used conservatively in spotted owl habitat.

Timber harvest levels appear greatest on the Carson National Forest where few spotted owls have been confirmed. Timber harvest levels on Santa Fe National Forest have been reduced in areas where spotted owls are known to occur. Isolation of spotted owl pairs and small populations distributed over large areas of fragmented landscape prompt concern because if they are lost, the species disappears from entire landscapes it once inhabited. Since the spotted owl was listed, planned timber sales have mostly avoided the owl's habitat. However, in the Vallecitos Federal Sustained Yield Unit in Carson National Forest, sales are still being planned in potential spotted owl habitat despite unconfirmed sightings of spotted owls in 1993.

Lesser threats to the spotted owl include human activities that produce extremely localized effects, but that may ultimately prove to have a large collective impact. Among them are unregulated fuelwood harvesting, grazing (particularly in riparian areas), and recreation developments at ski areas. All of these activities have the potential to degrade spotted owl habitat including habitat for the owl's prey.

Upper Gila Mountains

The Upper Gila Mountains RU contains the largest known number of Mexican spotted owls with approximately 55% of known spotted owl territories (Ward et al. 1995). The owl also appears to be more continuously distributed across this RU than any other (II.B). The apparent gap in owl distribution in the center of Figure II.B.6 reflects incomplete information from Tribal lands rather than an actual discontinuity within the owl's range.

Potential Threats

Spotted owls throughout the RU are found primarily in mixed-conifer and pine-oak forests (Ganey and Dick 1995), often in conjunction with canyon terrain. The primary threats to spotted owls and their habitat are timber harvest and catastrophic fire, not necessarily in that order. Both threats could destroy forest habitat with the structural features used by spotted owls, and both could operate over large spatial scales.

Other threats within this RU include indiscriminate fuelwood cutting and overgrazing by both wildlife and livestock. These threats are not as widespread or severe as the threats discussed above, but they can be significant in some areas. Fuelwood cutting is a problem in some areas primarily because people remove (usually illegally) large oaks. These trees appear to be critical to owls in some areas or habitats, particularly the pine-oak type (Ganey et al. 1992). Fuelwood harvest can also result in loss of large snags and down logs. Both of these habitat components are also apparently important to the owl, either directly or indirectly through effects on the prey base (Ganey and Dick 1995, Ward and Block 1995).

Overgrazing is suspected to be detrimental in some areas and can affect both habitat structure and the prey base. Effects on the prey base are difficult to quantify, but removal of herbaceous vegetation can reduce both food and cover available to small mammals (Ward and Block 1995). This may be especially true with respect to voles, which are often associated with dense grass cover. Direct effects on habitat are obvious in some places, particularly with respect to browsing on young Gambel oak. In some areas, oak is regenerating well but unable to grow beyond the sapling stage because of this browsing. Coupled with loss of large oaks to fuelwood harvest, maintenance of most oak stems in a sapling stage suggests a very real possibility that large oak trees will not be replaced over large areas, resulting in the loss of an important habitat component. Grazing effects on habitat are also potentially significant in canyon-bottom riparian areas. We do not attribute these effects solely to livestock. Forage resources are shared by livestock and wild ungulates, and reducing numbers of both will likely be necessary to bring forage use to reasonable levels.

Basin and Range - West

Sprawling across southern Arizona and extreme southwestern New Mexico, the Basin and Range - West RU ranks as the second largest RU in the United States. Though it probably does not support as large a spotted owl population as the Upper Gila Mountains RU, the known population ranks third highest in the United States despite limited survey efforts in many areas. Therefore, the Team regards the Basin and Range - West RU as an important unit for the recovery effort.

Potential Threats

The Team perceives limited threats overall to spotted owls in the Basin and Range - West RU as the result of human activities. Very little timber harvest occurs in this RU, though some timber occurs in the Bradshaw Mountains of the Prescott National Forest and on the San Carlos Apache Reservation. The primary threats to spotted owls within this RU are catastrophic wildfire, recreation, and grazing. We detail below the nature and extent of these and other potential threats.

Historical efforts to suppress fire have allowed fuel loads to accumulate to dangerous levels within most of the wooded and forested vegetation types in this RU. For example, the 1983 fire in the Animas Mountains removed the coniferous forest from the higher elevations. Recent wildfires in the Pinaleno, Rincon, Chiricahua, and Huachuca Mountains also attest to the volatile situation in this region. We view the potential for catastrophic wildfire as the primary threat to spotted owls in the Basin and Range - West RU.

Many mountain ranges in the Coronado, Prescott, and Tonto National Forests are used heavily for recreation. This is partly because of their proximity to large urban areas (Tucson and Phoenix) and partly because of their international reputation for exceptional birding. Effects of recreation include development of roads, campgrounds, and trails, and also extraordinary use of those facilities. For example, a number of areas within the Coronado National Forest (e.g., Madera Canyon in the Santa Ritas, Garden and Ramsey Canyons in the Huachucas, and the South Fork of Cave Creek in the Chiricahuas) are world renowned for birding and receive thousands of visitors per year. Scheelite Canyon on the Fort Huachuca Army Base is visited often by birders specifically to view the pair of spotted owls that occur there. The Mexican spotted owl, in fact, is one of the more popular species sought by birders in this region.

Cattle grazing occurs throughout the RU. Impacts are greatest in the high desert grasslands, desert scrub, and riparian habitats found between mountain ranges. Moderate grazing pressures occur within mid-elevational encinal and pinyon-juniper woodlands; and grazing pressures are evident within higher elevational canyon stringers of pine-oak, mixed-conifer, and riparian forests. Perhaps the primary threat of grazing is to the low-elevation riparian forests. These forests may represent critical linkages among the mountain ranges. Modified and degraded riparian forests may inhibit dispersal

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among mountain ranges and gene flow among owl subpopulations.

Land ownership within the Basin and Range - West is a mosaic of public and private lands (II.B). Most major mountain ranges fall under Federal jurisdiction, with some private inholdings and other lands administered by the San Carlos Apache and White Mountain Apache tribes. Much of the shrublands and grasslands between mountain ranges are administered by the FS or BLM, but a fair portion is privately owned. Many of these private lands are used for cattle, which graze both in upland and adjoining riparian communities. Grazing in riparian communities is a concern because of the potential for negative impacts on areas that can provide dispersal habitat among mountain ranges. This mosaic pattern of jurisdiction by multiple landholders may impede coordinated management efforts for the owl.

Most land development within the RU is related to enhancing recreation opportunities. These include developing or expanding campgrounds (e.g., Twilight Campground in the Pinaleno Mountains, the loop turn at John Hand Lake in the Chiricahuas) or enlarging roads for safety (e.g., widening of Mount Lemmon highway in the Santa Catalina Mountains). Developments such as these often require removing trees, potentially altering owl habitat. Further, a rapidly increasing human population in the southwest portends increasing urban development which can potentially encroach upon owl habitat and also impact groundwater regimes, potentially impacting riparian systems.

Evergreen oak and pinyon-juniper woodlands receive the most pressure from fuelwood harvest. Historical harvest of mature mesquite stands within the shrubland and grassland areas may have contributed to the demise of the riparian forest, thus continued harvest of mature mesquite in these areas may be a concern.

Basin and Range - East

The Basin and Range - East RU lies mostly within New Mexico and supports the second largest known number of Mexican spotted owls in the United States. It adjoins four U.S. and one Mexican RUs. Mexican spotted owls occurring in the Sacramento Mountains have been exposed to various disturbances for more than a century. Natural disturbances include forest fires plus insect and disease outbreaks. Human disturbances include timber and fuelwood harvest, grazing, land development, and recreation. The cumulative effects of these natural and anthropogenic disturbances have resulted in a landscape that differs from that existing prior to European settlement. The threat of these disturbances to the owl's persistence cannot be quantified at this time, but certain incongruities are detectable. For example, owl density is relatively high on FS lands, but fecundity is quite variable over time and annual survival is unknown. Thus, even though the current population density may be high, we know nothing of population trends. Further, given existing forest conditions in this RU, threats of widescale habitat loss are real and immediate. Consequently, active management is needed to alleviate these threats while ensuring that adequate habitat will exist well into the future.

Potential Threats

The Team categorized potential threats to spotted owl recovery according to magnitude. Major threats pose immediate potential for causing declines in spotted owl populations, and minor threats present no such immediacy. Major threats, in order of potential effects, include (1) catastrophic, stand-replacement fires, (2) some forms of timber harvest, (3) fuelwood harvest, (4) grazing, (5) agriculture or development for human habitation, and (6) forest insects and disease. Minor threats are activities not currently extensive in time or space but that have been considered potential threats to the owl. These include (1) certain military operations, (2) other habitat alterations (e.g. power line and road construction, noxious weed control), (3) mining, and (4) recreation.

Existing dense forest conditions makes much of the Basin and Range - East RU vulnerable to catastrophic fire. Such stand-replacing fires have been documented in the Sacramento Mountains since the 1950s and continue to the present (e.g., the Burgett and Bridge fires in 1993 and 1994, respectively). Similar fires occurred in the

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Smokey Bear Ranger District (Hanks and Dick-Peddie 1974) and other mountain ranges in the Basin and Range - East RU (Plummer and Gowsell 1904, Moody et al. 1992). Failure to address this potential for fire by reducing fuel levels and fuel continuity will inevitably lead to more and larger fires resulting in the continued loss of owl habitat.

Past timber harvest practices have left a few remnant old-growth stands and residual pockets of pre-harvest trees in the Sacramento Mountains. Trees older than 200 ybh (years at breast height) can be found in these remnant stands and pockets. Many of these stands, however, are small (<4 ha [10 ac]) and exist as smaller groves amid the younger coniferous forests. Our observations indicate that these remnant patches are critical to the Mexican spotted owl, particularly for nesting and roosting. This situation is similar to spotted owl use of second-growth redwood in northern California. Both cases should be viewed as exceptional and regionally dependent processes. Regardless, many of these older patches are on the verge of senescence and decline. Few patches are on a trajectory to replace remnant patches as they are lost in the short term. Thus, timber harvest in the immediate future must avoid altering these remnant patches in such a way as to accelerate their decline. Rather, forest management must strive to create replacement patches as quickly as conditions allow to ensure that these unique habitat patches are sustained through time.

Insects, plant pathogens, and dwarf mistletoe comprise a third important agent of forest disturbance in the Sacramento Mountains (Plummer and Gowsell 1904, Stevens and Flake 1974, Hessburg and Beatty 1986, Hawksworth and Conklin 1990, Archambault et al. 1994). Principal organisms are western spruce budworm, round-headed beetle, white pine blister rust, dwarf mistletoe, *Phellinus schweinitzii*, and other fungi. These organisms operate at scales ranging from single trees to landscapes. Not only are insects and tree diseases fundamental determinants of forest structure and function (Attiwell 1993, Haack and Byler 1993), but forest structure and composition influence population levels of these organisms. As a result, the dense forest conditions existing in the Sacramento Mountains have allowed some insects and diseases to increase from endemic to epidemic levels. Clearly, forest management that decreases forest density, primarily by thinning from below, will help to control populations of some of these organisms.

Grazing by domestic livestock and elk in this RU has altered botanical cover, specifically plant composition and structure. Range management has been oriented toward domestic livestock and other wildlife goals, but not for the owl. Regardless of its past orientation, grazing can affect owl habitat and prey populations in conflicting and poorly understood ways (II.D). Effects of grazing are largely manifested in meadow and riparian areas, but effects within forests cannot be easily discounted. Implementation of the grazing recommendations (provided above) are needed to understand and address potential effects of grazing on the spotted owl.

Agriculture and concentrated human developments occur in the Rio Grande Valley and to a lesser extent in the Sacramento Mountains. Both may affect dispersing or wintering owls by reducing the spatial extent of habitat. Management that emphasizes the restoration of riparian forests may benefit both resident birds in the Sacramento Mountains and birds migrating between mountain ranges.

At present, the Team considers the impacts of recreation to be of minor importance to the RU's spotted owls; but we have no studies or documentation to substantiate our position. Recreation noise from motorcycles and snowmobiles has been implicated as a potential threat. Indirect habitat disturbance from recreation may occur on a local scale but is also undocumented. Other activities include camping, hiking, birding, hunting, off-road vehicle use, snowmobiling, and skiing. Many private land inholdings are summer homes or camps and are also a source of recreation in spotted owl habitat.

Mexico

Presently, limited information on the biology of the Mexican spotted owl and on land management activities within Mexican RUs precludes the provision of extensive management recommendations. However, the information available indicates that spotted owls use forest types not typically found in the United States and that land-management practices differ substantially in Mexico from those in the U.S. The Team proposes that the general recommendations be applied within the Mexican RUs where appropriate. The Team strongly recommends that RU working teams (see Part IV) develop management recommendations for Mexico more fully.

The Mexican spotted owl is typically found in montane habitats where the vegetation is dominated by pines and oaks. Although spotted owls in the U.S. also use pine-oak forests, they vary somewhat in composition and structure from similar forests in Mexico. However, within Mexican pine-oak forests, spotted owls appear to favor canyons, as they do in many of the areas used in the U.S.

Because social and economic systems in Mexico differ from those in the U.S., activities that take place within potential spotted owl habitat differ somewhat between the two countries. Whereas grazing, fire, timber harvest, and fuelwood harvest are threats common to both countries, other threats are unique to Mexico and some to specific RUs.

Potential Threats

***Sierra Madre Occidental* - *Norte*.**—The primary threat is land conversion for subsistence agriculture. Impacts of this threat include the loss of spotted owl habitat, soil loss, and erosion. A related threat is overgrazing by livestock. Historically and through the present, forest lands have been cleared to create pastures for cattle; the cumulative effects of these practices have modified spotted owl habitat. Although extensive timber harvest occurs within this RU, most harvest occurs in the uplands and is not a direct threat to spotted owls found in canyons. Whether or not timber harvest indirectly affects the owl is unknown, but could be a concern worth addressing through research.

***Sierra Madre Oriental* - *Norte*.**—Timber harvest and grazing are the primary threats within this RU. The main effects of these threats is to further fragment an already disjunct population.

***Sierra Madre Occidental* - *Sur*.**—Primary threats within this RU are fuelwood harvest, timber harvest, charcoal production, grazing, and agricultural development. Fuelwood harvest often entails cutting snags and the harvest of riparian plant species, both of which are critical components of spotted owl habitat. Timber harvest in itself is not a direct threat to spotted owl habitat. However, harvest methods that entail rolling logs from higher to lower sites result in soil loss and erosion, thereby affecting the habitat of the owl and its prey. Fire is considered only a moderate threat because of the disjunct distribution of owls in canyons and because limited efforts towards fire suppression have allowed natural fire regimes to persist. Fire, however, can possibly destroy spotted owl habitat under the right conditions. Livestock graze throughout the year within spotted owl habitat, and the cumulative effect of this grazing affects prey habitat and spotted owl habitat structure. Type conversion of forests for agriculture also occurs within this RU.

***Sierra Madre Oriental* - *Sur*.**—The potential threats in this RU parallel those within Sierra Madre Occidental - Norte RU. The primary difference is that this RU probably contains the best and most extensive habitat within any of the Mexican RUs, thus threats can occur over a much greater area.

***Eje Neovolcanico*.**—The primary threats in this RU are those associated with population expansion and industrial development. Specifically, industrial development can lead to loss of habitat and an increase in pollution. Other threats include management to control insects and disease, fire suppression, grazing, and agricultural development.

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C. MONITORING PROCEDURES

The Team has assimilated, reviewed, and analyzed data generated by the Mexican Spotted Owl Monitoring Program of FS Region 3. We have also compiled and reviewed data from the BLM and the FS Region 4 in Utah, and FS Region 2 in Colorado. Here, we offer an alternative design for monitoring the Mexican spotted owl population within the three core RUs. We also provide recommendations for monitoring habitat throughout the owl's range. This proposed monitoring program will evaluate population and habitat trends as required by the criteria for delisting the species (III.A). The philosophy of our proposed monitoring scheme is to measure the critical variables--changes in owl numbers and changes in habitat--needed for delisting the species.

For the purposes of recovery and understanding effects of land management activities on the Mexican spotted owl, monitoring should determine with adequate reliability temporal changes in the owl population and its habitat when in fact such changes are occurring. An effective monitoring program requires measuring changes in habitat quantity, estimating population size of territorial owls, and determining key demographic parameters including survival, recruitment, and reproduction, all of which influence population size.

Habitat monitoring will rely heavily on both remote-sensing of habitat across the range of the bird and field measurements of habitat variables before and after treatments. Population monitoring is based on mark-recapture theory and Cormack-Jolly-Seber modeling approaches, similar to Pollock's robust design approach (Lefebre et al. 1982, Pollock 1982, Kendall and Pollock 1992). To our knowledge, a systematic habitat monitoring approach as extensive and intensive as the one we propose has never been implemented. In contrast, a prototype design for population monitoring was implemented in Olympic National Park, Washington (Noon et al. 1993, E. Seamen pers. comm.) to monitor a northern spotted owl population.

Accurate and efficient protocols for both habitat and population monitoring require pilot studies to estimate recapture probabilities, and to estimate variances associated with each of the population parameters and each of the habitat variables. For population monitoring, these estimates can then be used to determine optimal quadrat size and numbers of quadrats required within predefined strata and RUs. Funding was allocated in 1994 to further refine the proposed population design with a small field trial involving four quadrats. Results of this field trial validated the study design provided qualified personnel conduct the work (May et al., in press). A larger pilot study is needed to refine parameter estimates for actual implementation of the proposed design. For habitat monitoring, separate pilot studies will be needed to establish sampling designs, including sample size requirements.

HABITAT MONITORING

The habitat delisting criterion states that habitat monitoring must be implemented (1) to track changes in the quantity of macrohabitat and (2) to verify that microhabitat changes within treated stands meet the intent of the Recovery Plan. Thus little, if any, owl habitat can be lost if this goal is to be met. Further, habitat quality cannot decline significantly. A concern of the Team is that habitat quality cannot be adequately assessed, particularly with remote-sensing data. To alleviate this concern, our recommendations also include field measurements of microhabitat characteristics within treated stands. However, we reiterate that macrohabitat quantity should also be monitored on a rangewide basis.

Macrohabitat

The purpose of rangewide monitoring is to track gross changes in habitat as the result of disturbance, from both natural (e.g., fire) and anthropogenic (e.g., timber harvest, prescribed fire) causes. Given the extent of the area to be monitored, remote-sensing technology will be required. An imagery baseline should be established within six months of Recovery Plan approval using LANDSAT Thematic Mapper imagery (currently available in the FS Region 3 Geometronics Remote-Sensing Laboratory). The imagery for potential owl habitat and surrounding areas should be aggregated, georeferenced, and merged with vector map data to provide image maps. These image maps may be used both as general planning tools and as a baseline for detecting change. The 30-m (98-ft) spatial resolution of the LANDSAT Thematic Mapper imagery is adequate to detect both anthropogenic and natural change across large land areas. Changes that can be detected include wildfire scars, timber harvests, gross changes in forest health, and possibly the addition or removal of roads, large developments and other cultural features, and fluctuations in grazing practices.

In a standard change-detection analysis, two image data sets are co-registered and then subtracted from each other. The resulting difference image highlights changes across the area covered by the image data sets. An additional image data set will need to be purchased in the future to perform change detection. The additional data set may be either LANDSAT Thematic Mapper (TM) data or LANDSAT Multispectral Scanner (MSS) data. A TM data set would be preferred, but MSS data could be substituted and would provide adequate spectral and spatial resolution to perform useful change detection.

The baseline TM data set can also be used to develop a generalized regional vegetation cover map, using standard supervised and unsupervised image classification techniques with TM bands 4, 3, and 2. The literature indicates that the 4,3,2 band combination is most useful for vegetation analysis. Developing a vegetation map would also require the integration of 1:250,000 digital elevation data to account for the effects of varying slope aspects and elevation on vegetation patterns.

Texture analysis techniques may be used to assess vegetation structure and density across large areas using either the LANDSAT TM or MSS data. While texture analysis applications in vegetation analysis have appeared frequently in the literature, the methodologies are not as widely accepted as image classification techniques, so they must be considered experimental.

Given the resolution possible with the tools and information available, remote sensing monitoring techniques will provide an estimate of macrohabitat trend. Within five years of creating the imagery baseline, participating agencies should produce a report assessing changes in vegetation composition, structure, and density. This will provide an interim checkpoint to determine if the delisting criteria can be met at the end of 10 years.

Microhabitat

Microhabitat monitoring is required because remote sensing is largely insensitive to subtle intra-stand changes that may enhance or degrade owl habitat. Microhabitat monitoring will entail measuring habitat variables before and after silvicultural or prescribed fire treatments designed to maintain, improve, or create owl habitat. This monitoring is to verify that treatments (silviculture, fire) are meeting their stated objectives. We acknowledge that many treated stands will not meet the desired future condition in 10 years, but the trajectory on which a stand is placed can be modeled to evaluate if it is moving towards owl habitat. This knowledge is needed to demonstrate that any short-term losses in macrohabitat will be partially offset as stands mature into owl habitat. If adequate acreage of vegetation is moving towards owl habitat, our confidence in long-term habitat stability will be enhanced.

Sampling units will be treated stands. Within these stands, an adequate number of vegetation sampling points must be established. The exact number of sampling points needed will be dictated by the most variable characteristic (likely snag density; Bull et al. 1990). Points should be sampled prior to initiating a treatment, resampled following the treatment after allowing adequate time for the area to equilibrate from temporary disturbance effects, and then at five-year intervals. The variables measured can then be input into a vegetation model to estimate stand characteristics at different points in time.

At a minimum the following variables should be measured and assessed: (1) tree diameters by species, (2) tree basal area by species, (3) size-class distributions of trees, (4) log volume by size class, (5) canopy cover, (6) snag diameter, and (7) snag basal area. We strongly advocate that additional variables be included that might be relevant to monitoring other ecosystem attributes. The return in critical monitoring information derived by expanding the variables measured would far outweigh any additional costs, assuming that the new variables are not highly correlated with the variables suggested above.

POPULATION MONITORING

Monitoring habitat as a singular effort will not adequately reveal the true status of the owl population. Relatively long-lived birds with a high (~0.89) adult survival, Mexican spotted owls may live 16 years or more once they reach adulthood. However, an intense period of mortality during the first year could produce population consequences that habitat monitoring would not detect. Habitat quality could decline from various natural processes or anthropogenic activities, yet the territorial population would remain unchanged because of site fidelity among existing birds and recruitment of floaters. Young might still be produced, but would not survive to be recruited into the territorial population because of poor habitat quality, limited habitat availability, or because their inexperience would not allow them to survive and disperse during their first year.

A limitation of this proposed monitoring scheme (and all known approaches) is that only territorial birds are monitored. The total or proportional number of floaters (*sensu* Franklin 1992) remains undetermined and unmonitored relative to the target population.

Because nonterritorial birds are not directly monitored, we want to guard against an undetected decline in the total population of spotted owls when the territorial population remains stable. We suggest the following procedures to evaluate trends in the nonterritorial population. First, the age of birds that establish territories will indicate the size of the nonterritorial population. If new territorial birds are only one year old, then they have never existed as floaters in the population. Thus, a decline in the age of territorial birds suggests that the nonterritorial population is low or declining (Franklin 1992). Second, the presence of unfilled territories would suggest that an inadequate floater population exists, and hence that a decline in the population is taking place.

In the following, we outline a suitable framework and statistical estimation approach for monitoring owl populations in 3 RUs. However, critical design and sampling details, such as sample sizes and delineation of strata, have been omitted, and must be developed by an implementation team as data become available to make those decisions.

Target Population

The target population for the abundance estimate is territorial Mexican spotted owls (exclusive of floaters) in the Upper Gila Mountains, Basin and Range - West, and Basin and Range - East RUs. Thus, all potential owl habitat in these 3 RUs must be included in the sampling frame. All land management jurisdictions are encouraged to cooperate in providing access and resources to monitor the entire owl population

Sampling Units

Sampling units will consist of 50 to 75 km^2 (19 to 29 mi^2) quadrats randomly allocated to habitat strata. Quadrats will be defined based on ecological boundaries such as ridge lines and watersheds to reduce edge effects. Selection of quadrat boundaries must emphasize edges that are unlikely to traverse owl territories, so that the errors of including a territory in multiple quadrats or in no quadrat do not occur. The exact number of quadrats and their size will depend on the specifics of implementing the monitoring scheme and results of pilot studies.

In general, the population monitoring scheme will require: (1) determining strata that represent different owl densities or habitat types occupied by owls within each RU; (2) determining quadrat size which should be sufficiently large to reduce edge effects and small enough to allow a minimum of four surveys per quadrat in the survey season limited to 1 April to 30 August (initial approximation of quadrat size is 50 to 75 km^2 [19 to 29 mi^2] [May et al., in press]); (3) defining the sampling frame of quadrats in each stratum such that quadrats are relatively equal in size and have boundaries selected to minimize edge effect; (4) selecting a random sample of quadrats from each stratum the first year, and then randomly replacing 20% of the sampled quadrats each year with quadrats randomly selected from the currently unsampled quadrats (with quadrats in the initial sample potentially removed, and then possibly included in the sample again at a later time); and (5) developing protocols for conducting field surveys (likely different from past FS protocols because of the different goal of the proposed procedure from past goals).

Sampling Procedures

Stratification

LANDSAT multispectral scanner imagery with 30-m spatial resolution would be suitable for defining habitat strata within each RU, and thus the sampling frame of quadrats for each stratum. Approximate density of territorial owls within strata can then be used to allocate survey effort (number of quadrats) to strata. The optimum allocation of survey effort is one that would minimize erroneous estimation of spotted owl abundance. Optimal allocation of quadrats to strata will probably not be in proportion to strata size. More likely, optimal allocation will mean that a higher percentage of quadrats in strata with high owl densities will be sampled. Optimal allocation might also take into account the cost per quadrat because of potential differences in the cost of measuring quadrats within different strata. Strata should be computed both as projected (ignoring topography) and as surface (incorporating topography) areas because differences in topography affect vegetation type.

Selection of Quadrats

Within strata, quadrats will be randomly selected for inclusion in the sample. We suggest that 80% (randomly selected) of the previous year's quadrats be revisited the following year. The other 20% of the previous year's quadrats should be removed from the sample, and a replacement sample of quadrats not sampled the previous year should be substituted. Quadrats removed one year can included in the sample in following years provided that it is randomly selected and that at least one year has elapsed since it was last sampled. This procedure means that the average number of years that a particular quadrat remains in the sample is 4.5 years. Inclusion of new quadrats into the sample each year guards against management practices within the sampled quadrats not being representative of those practices occurring elsewhere. This rotation of quadrats included in the sample will provide a smaller variance because observations are correlated across time and many quadrats will be sampled repeatedly, but still provides a representative sample of the available quadrats.

Sampling Within Quadrats

Sampling procedures within a quadrat will include (1) assigning survey stations to ensure adequate coverage and a standardized density of such stations among quadrats; (2) allowing for a minimum of four complete (i.e., all call points sampled) surveys through each quadrat; (3) conducting nighttime surveys from survey stations to map general locations of spotted owls and to estimate per-visit detection probabilities; and (4) conducting daytime (auxiliary) surveys and mousing to find roosting and nesting spotted owls, determine if a mate not detected

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during nighttime survey is present, determine number of young present, and capture and color-mark all spotted owls found. For each spotted owl found, the center of its activity area must be determined as either in or out of the quadrat.

Proper timing of surveys maximizes efficiency in locating spotted owls. We recommend that nighttime surveys be conducted within 3 hours following sunset. Owls detected at dusk are near diurnal roosts and thus provide an optimal starting point for confirming pairs and reproduction during daytime surveys. Similarly, daytime surveys should begin at or near sunrise (preferably just before) as owls are returning to their roosts.

Banding Birds

Marking individual birds with FWS leg bands and color bands for visual identification provides greater validity in the estimation of the owl population size on the quadrat because the assumptions of the mark-recapture methods can be tested. Conceivably, owl population size on quadrats with high densities of owls might be underestimated without banding because two different birds might be counted as only one. Conversely, on quadrats with low densities, a single bird might be counted as 2 birds, biasing the population estimate high. Individually marking birds will eliminate some of this potential bias. Second, banding birds is necessary to estimate annual survival on quadrats that are sampled for two consecutive years. Third, capturing birds allows more careful aging of individuals; hence, the resulting age structure data are more useful in assessing the impact of floaters in the population. Finally, minimum estimates of dispersal and emigration from the quadrat can be assessed with banded birds that are located off the quadrat. Although the cost of the population estimation procedure may be increased by up to 40% by individually marking birds (May et al., in press), the Team feels the additional information and rigor provided by marking birds is justified.

Statistical Analysis

Noon et al. (1993) provide the following statistical discussion.

Estimation of Capture Probability

The described spotted owl surveys will provide data regarding the number of territorial owls detected and determined to have their activity centers within the survey plots. It is unlikely that all owls with activity foci lying within these plots will be detected, and capture probabilities will therefore be less than 1. Capture is defined as either physically capturing and uniquely marking an individual or resighting its unique color band combination without physically recapturing it. Thus, the per-visit capture probabilities must be estimated to "correct" the count statistics and reflect the true number of territorial birds with activity centers within quadrat boundaries.

Per-visit capture probabilities can be estimated using data on the capture histories of individual owls on the quadrats. The four surveys will be conducted during a relatively short period, so it is appropriate to use capture-recapture models for closed populations (e.g., Otis et al. 1978, White et al. 1982, Pollock et al. 1990). Per-visit capture probabilities may vary by visits, strata, RUs, and years. However, substantial gains in the precision of capture probability estimates would be achieved if they could be estimated using data pooled over visits, strata, RUs, or years. Standardized survey protocol within and among quadrats using field crews with communal training should decrease the variation in per-visit capture probabilities.

Heterogeneity of per-visit capture probabilities across individuals should be examined. If heterogeneity is found, estimators developed under model M_h of Otis et al. (1978), such as the jackknife (Burnham and Overton 1978, 1979) and Chao's (1987, 1988, 1989) estimator are appropriate. If heterogeneity is not serious, models with data pooled over visits, strata, RUs, and years should be considered.

Capture probability estimates resulting from these modeling efforts will pertain to the probability of detecting and capturing an individual spotted owl during a single survey visit. Capture history data, and hence the capture probability estimates, will be restricted to those spotted owls with a nest or focus of activity within the area being sampled. The density estimation procedure (see below) actually requires an estimate of the probability of detecting and capturing a spotted owl at least once during an entire season. Given owl presence, the estimated probability of detecting and capturing an owl during the season using surveys is given by

$$\hat{p}_k = 1 - (1 - \hat{p})^k,$$

where p_k is the probability of detecting and capturing a spotted owl at least once during k visits, and p is the single-visit capture probability.

The above scheme for estimating capture probability should work well with owls initially detected from survey points within the quadrat. However, these capture probabilities are not applicable, by themselves, to other pair members found during daytime visits or to spotted owls located other than by calling from survey points. To include data from pair members located during daytime visits, we consider their capture probability as the product of the probability of capturing a pair member from survey points times the probability of capturing the other pair member during a daytime visit given capture of one mate from survey points. The first probability in this product is obtained using capture histories (i.e., capture probabilities) of birds detected from survey points as previously described. The second, conditional probability must be obtained using data from daytime visits and captures only.

Auxiliary or daytime visits can be viewed in the context of removal modeling (e.g., Zippin 1956, 1958; Otis et al. 1978; Ward et al. 1991). The primary purpose of daytime visits is to determine pair and breeding status of birds detected from survey points. Auxiliary visits may or may not be terminated after capture of the mate, depending on whether data on reproductive success is adequately obtained.

Estimation of Density Per Quadrat

Each quadrat requires two parts to the estimation process. First, estimation of apparent density by

$$\hat{D}^*_i = \frac{n_i}{a_i} = \frac{n_{si} + n_{ai}}{a_i},$$

which is the total number of spotted owls detected and having activity centers in quadrat i (n_i), based on both survey (n_{si}) and auxiliary (n_{ai}) visits divided by the area of the quadrat (a_i).

Next, apparent density is adjusted for those spotted owls that maintain an activity center within the quadrat but were not detected during a survey visit. The adjustment for the survey visit is the reciprocal of $\hat{p}_k$, the probability of a spotted owl being captured at least once on a given survey based on k visits to quadrat i. Note that $\hat{p}_k$ pertains only to the n_{si} animals detected during the survey point visits of quadrat i, not to birds detected on auxiliary visits. If auxiliary visits are made to determine pair or reproductive status, any additional pair members that are detected contribute to the density estimate for quadrat i. As discussed previously, their capture is conditional upon an initial capture from a survey point. To adjust the count of the n_{ai} owls detected on quadrat i during auxiliary visits, we divide the count by the probability of detecting a pair member during k auxiliary visits ($\hat{p}_a$), given detection and capture of its mate from survey points. Thus, we would estimate density on quadrat i as

$$\hat{D}_i = \frac{\left[\frac{n_{si}}{\hat{p}_k} + \frac{n_{ai}}{\hat{p}_k \hat{p}_a}\right]}{a_i}.$$

Estimation of Density Per Stratum

Once we have density estimates for each quadrat within a stratum, they can be combined into an overall mean estimate of density for the stratum. Because quadrats are not the same size, weighting of the quadrat density estimates by area is essential, so that

$$\hat{D} = \frac{\sum_{i=1}^{m} a_i \hat{D}_i}{\sum_{i=1}^{m} a_i},$$

where m_j is the number of quadrats in stratum j. To obtain population size estimates for each stratum (j), multiply by the area of the stratum (A_j) so that $\hat{N}_j = \bar{D}_j \cdot A_j$. Note that A_j may change through time as habitat changes and quadrats are moved from one stratum to another.

An estimate of overall abundance for RU u is then $\hat{N}_u = \sum^{m_u} \hat{N}_j$, where m_u is the number of strata in RU u.

Variance Estimators

With stratified-random sampling, we usually have simple variance equations because the stratum means of totals are independent between strata. Here, this is not the case because corrections for spotted owls not seen are common across strata and induce the need for covariance terms. These variance equations will need to be developed. Specific closed-formed solutions may not be possible for the variance estimates. Thus, estimating the variance components by bootstrap methods may be more feasible.

Cormack-Jolly-Seber Models

Cormack-Jolly-Seber (CJS) models (Lebreton et al. 1992) can be used to estimate age-specific apparent survival (ϕ_a) and recruitment to the territorial population (B). We suggest using CJS modeling procedures as outlined by Lebreton et al. (1992), Burnham and Anderson (1992), Pollock et al. (1990), and Burnham et al. (1987). This approach is demonstrated by White et al. (1995) for the analysis of data from the demographic study areas. We suggest that data from all quadrats within a stratum (or even larger area) can be pooled to estimate apparent survival and recruitment.

Both the apparent survival (ϕ) and recruitment (B) are biased estimates of true survival (S) and true recruitment rates because the quadrats do not have geographic closure. For survival, $\phi = S - E$, where E is the emigration rate off the quadrats. For recruitment, $B = R + I$, where R is true recruitment and I is immigration onto the quadrats. If the area of the combined quadrats were used in a single demographic study area, the bias of ϕ and B would be smaller because the probability of birds emigrating off of and immigrating onto a large single area would be smaller than for a collection of small quadrats representing the same area. However, if we assume that this bias is somewhat constant across time, then tests for changes in ϕ and B across time with models such as ϕ_T as demonstrated by Burnham et al. (1994) provide a potent tool to assess changes in these population parameters through time. The optimal size of quadrats is dictated by keeping them large enough that reasonable estimates of the number of territorial birds present can be accomplished, while small enough so that an adequately large sample of quadrats is possible to estimate precisely the among-quadrat variation.

We would not suggest that ϕ and B be used to compute λ in a Leslie matrix model as was done with the demographic study areas by White et al. (1995). Biases caused by emigration and immigration make any estimate of λ computed from these parameters biased as well. Furthermore, the main objective of the quadrat surveys is to provide an unbiased estimate of the total number of territorial owls so that an unbiased estimate of λ can be obtained as $\hat{\lambda} = \hat{N}_{t+1} / \hat{N}_t$.

Estimates of juvenile apparent survival obtained from the CJS model with banding data from juvenile spotted owls will probably not be useful from the pooled quadrat survey data because the emigration rate of this population segment will be quite high as they disperse away from their natal territories.

Personnel

Quality work cannot be completed without capable people who desire to perform well. Owl surveys are difficult to conduct. To achieve accurate survey results requires a certain combination of physical and mental traits. The ideal candidate for spotted owl survey work must be physically capable of negotiating difficult terrain and doing so after dark. The mental demands include the intellectual capacity to understand the nuances of the work, the perseverance to succeed under adverse conditions, the ability to follow directions, and the discipline to be patient. Rigorous training to certify people to conduct monitoring is a critical step to ensure that qualified people implement the procedures.

Restrictions on duration of work day, night time work, and camping near survey sites can lead to inefficiency. Effective inventory and monitoring may often require personnel to survey between dusk and 2300 hrs and prior to sunrise the next morning if an owl is detected the previous night. Not permitting camping at sites or not allowing more than 8-hour work days is an ineffective survey strategy. Thus, cost and effort for determining occupancy or reproduction in a given territory may be doubled or tripled. Not allowing personnel to survey along marked ridge lines at night (i.e., off roads) may result in inadequate survey of an area. Competent, qualified, eager personnel can conduct such activities safely and with desired results as demonstrated by May et al. (in press).

Training

Training is the most important mechanism for ensuring quality data and standardization. The current certification program employed by the FS should continue, but in a more intense fashion. High-quality photographic media, including video tapes of proper procedures, should be incorporated. Use of a map, compass, and GPS system, and recording spatial information with Universal Transverse Mercator (UTM) coordinates (Grubb and Eakle 1988) are critical. Additional training for recording information on data forms, maps, and in an electronic data base is required (see below). Certified owl biologists should be tested routinely on their ability to complete data forms and plot locations correctly. A standardized procedure for storing all information also needs to be developed and enforced.

All training must be reinforced with adequate (4-day minimum) field exercises followed by periodic reinforcement of learned skills. Although initial skills may be provided with the certification process, reinforcement through feedback on procedures and results is required. An electronic data entry program will help to standardize inputs and reinforce proper documentation procedures. Such a routine will also indicate progress of the monitoring program and identify personnel or administrative units that need additional training. Further, additional training should include periodic visits by program supervisors to review field procedures. Incorrect observations may not necessarily be detected on data forms.

We also suggest a greater emphasis on identification of spotted owl age classes (juvenile, subadult, and adult) as described by Forsman (1981) and Moen et al. (1991). This valuable information may be obtained if observers take binoculars on surveys. Information on age structure may prove useful for identifying changes in demographic trends.

All survey routes and results need to be summarized in a standardized manner on media that can be entered into a Geographic Information System (GIS). Thus, field personnel will require training on use of map, compass, and GPS. In addition, a standardized map system and symbol set is paramount. We recommend a 7.5" USGS topographic map. This map type is readily available in paper and digital form. We also insist that field personnel record UTM coordinates. This will allow rapid updating of digital maps of owl locations.

Computerized Data Entry and Summarization

A major weakness of past inventory and monitoring programs has been the lack of accessibility to data; as a result, few summaries and analyses were prepared. This scarcity of data examination appears to be due to the lack of a central, accessible, computerized database where field forms are regularly entered for computer analysis. Field workers submitting data forms but not receiving feedback from their efforts nor a copy of the master database for them to review leads to errors that are difficult to rectify retroactively. We suggest that field workers who collect the data should also be responsible for data entry into a standardized computer form. The benefits would be twofold.

First, a computerized data entry form would guarantee that only admissible codes are used because invalid codes would not be accepted by the computer, and correct entries would be

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needed in all data fields before the user could proceed. Quality control would be facilitated via an interactive computer data entry interface. With such a data entry program, data from different jurisdictions of all involved land management entities would be compatible.

Second, once the data have been entered, summaries can be produced with standard summary programs. At a minimum, field workers should be able to produce summaries of data they entered, and make comparisons with past years and maybe other geographic areas. The main reason for this instant feedback is to encourage field personnel to examine their own data plus get a temporal and spatial perspective of existing data. Field workers would have a much better picture of how their data fit into the overall effort and would have access to data in the master database. Simple graphs and tabular summaries should be available via a menu system. This feedback would also promote greater cooperation in future surveys and makes the field worker feel a part of the complete process.

Creation of a master database on an accessible computer network (such as the World Wide Web [WWW] on Internet) has another, less apparent, benefit for the program. From this master database, region-wide summaries could be generated. Annual summaries would help detect trends in the data. Sophisticated statistical analyses could be programmed to implement tests for trends in the data. Safeguards would be necessary to limit access to the data, particularly sensitive site locations, to only authorized persons. Finally, scrutiny by outside reviewers would improve the integrity of the database.

To implement the above scheme, two pieces of software need to be written. The first is the data entry system, for which extensive error checking should be coded into the software. Data entered by a field worker would be appended to the master data file only after passing a stringent series of integrity checks. The second is a data summary program that would be menu driven and allow the user to summarize his/her own data plus other data of interest. We presume that modern PC computer software systems and access to a computer network should make this software development fairly easy. Once the field season is completed, each land management entity and their respective subunits should be able to obtain graphical summaries as well as statistical summaries in tabular form.

Costs

The cost for implementing the population monitoring scheme should include hiring a principal investigator to design this survey and coordinate sampling efforts. Field crew leaders will be necessary for supervising study logistics and field technicians will be required to conduct surveys. In addition, while models exist for estimating total population size through time, models of multiple capture probabilities require some independent work. All field personnel hired to conduct the pilot study and subsequent monitoring program must be qualified and trained.

Our initial estimate of the costs to fully implement the proposed monitoring scheme is approximately $1.2-1.5 million per year. Based on the delisting criteria, monitoring must continue for a minimum of 15 years.

Costs for implementing macrohabitat monitoring are unknown. However, much of the needed remote-sensing coverage exists or is being obtained as a tool for implementing ecosystem management. Thus, additional costs attributable to the spotted owl should be minimal. Costs of implementing microhabitat sampling are difficult to estimate without knowledge of the number of plots to be sampled. We assume, however, that sampling an area pre- and post-treatment is already required as a standard part of activity implementation; consequently, the cost attributable to owl monitoring would entail those associated with measuring additional variables specific to the owl. Thus, the total costs of habitat monitoring should be relatively minimal beyond that already required or in the process of being developed independent of the spotted owl.

Potential Experiments

Many habitat variables important to Mexican spotted owls cannot be monitored by remote sensing. Further, it is important to ensure that adequate habitat is provided for key prey as well. Thus, we propose some potential experiments to relate habitat conditions to owl population dynamics where key habitat characteristics would be measured on the ground. On-the-ground monitoring of relevant habitat characteristics would quantify their change at a local (i.e., within quadrat) scale and relate them to owl population dynamics.

Population monitoring based on randomly selected quadrats provides the opportunity to conduct experiments to extend our knowledge of the impact of habitat manipulation on Mexican spotted owl population dynamics. We propose these experiments to produce credible, defensible, and reliable results (*sensu* Murphy and Noon 1991). Quadrats within the monitoring design may serve as experimental units for examining the effects of future management such as fires, grazing, timber harvest, and recreation.

Given that a treatment is identified prior to its occurrence, vegetation measurements can take place on the site of the expected treatment and a second, control quadrat that is selected based on its similarity to the expected treatment quadrat. This experimental design is not a true experiment, because the treatment is not randomly allocated to one of the pair of quadrats. However, this quasi-experiment is still more powerful in developing cause-and-effect relationships between habitat manipulations and owl population dynamics than the more common correlative designs used by past researchers (see III.D for further details on experimental design). Further, the capability to replicate the treatment exists because of the extensive number of quadrats that will be required for measuring changes in population size.

Areas where planned treatments result in some form of habitat alteration provide excellent opportunities for quasi-experiments. Vegetation measures should be taken immediately before and after the habitat-modifying event, and thereafter at 5-year intervals. Vegetation measurements that seem especially important to examine are tree size-class distribution, log size-class distribution, canopy cover, and shrub cover. Results from these experiments, coupled with results of population monitoring, will provide the basis for a predictive model of spotted owl habitat quality (assuming that owl density reflects habitat quality). Data on apparent owl survival and reproduction will also be available, which may relate to habitat quality more directly than owl density.

Alternative Designs for Population Monitoring

Drawing New Sample of Quadrats Each Year

Instead of drawing an initial sample of quadrats from the sampling frame and monitoring these same quadrats through time, an alternative approach would be to draw a completely new random sample of quadrats each year. For repeated sampling of a set of quadrats to be legitimate, normal activities that occur in spotted owl habitat should continue during the monitoring program, provided these activities meet the requirements of section 7(a)(2) of the Act by not likely jeopardizing the continued existence of the Mexican spotted owl. The main advantage of a new sample each year is that it guards against the potential for land managers to manage areas within the quadrats differently than the remainder of the landscape. The price of this protection is relatively great as illustrated by these four points: (1) the logistics of conducting the surveys each year would increase because of the new quadrats; (2) age-specific apparent survival rates and recruitment to the territorial population could not be estimated with the CJS analysis because birds would not be marked on the same area each year; (3) quasi-experiments to detect the relationship between habitat manipulations and owl population dynamics would not be possible; and (4) higher sampling intensities would be required because this design is less efficient for estimating change. Our proposed design is intermediate between sampling the same set of quadrats each year and a completely new sample each year. We obtain the benefits from both alternatives in that the correlation of measurements for a specific quadrat across years is used to lower the overall variance of our population estimate, making the design more efficient than complete replacement each year, yet we are guarding against the potential for sampled quadrats to be managed differently than other areas.

Conducting Surveys Less Often Than Yearly

Instead of surveying quadrats each year, effort and cost could be saved by conducting the surveys at longer intervals, such as every 5 years. An advantage of this approach is that costs will be lowered, and possibly more precise estimates of population size could be obtained by pooling money to conduct a few very good surveys instead of more frequent surveys with lower effort per survey. The main disadvantage of this approach is that age-specific apparent survival rates and recruitment to the territorial population could not be estimated with the CJS analysis because birds would not be marked frequently enough to obtain these estimates. For example, given an estimate of 0.89 for adult survival, only 56% of the initial population would still be alive after 5 years, resulting in small sample sizes of recaptured birds, and hence poorer precision of the survival estimates. Further, reproductive and annual survival rates and their variation across years are needed to realistically evaluate population viability. Finally, our ability to detect relationships between habitat manipulations and population dynamics would be greatly decreased because this approach is more sensitive to variability introduced by the years chosen for sampling.

Adaptive Sampling

Thompson (1992) has developed an adaptive sampling scheme to improve the efficiency of sampling clustered populations, such as is probably the case for Mexican spotted owls. Thompson's scheme is theoretically appealing because more effort is applied to areas where owls are located. Under this approach, quadrats adjoining a quadrat that contains some threshold number of spotted owls would also be sampled. Unfortunately, we cannot envision how to handle the logistics of adding some unknown number of quadrats to the sample when survey crews must be hired, trained, and outfitted with equipment and vehicles prior to sampling. We suspect the logistical overhead of this approach may make it impractical for monitoring owls on quadrats. However, as the theory and application of the adaptive sampling scheme is developed further, an innovative application of the technique may be possible with our proposed quadrat monitoring scheme.

CONCLUSION

The technology and expertise are available to monitor trends in Mexican spotted owl habitat and population size. Clearly, the objectives and design of the monitoring program must be defined explicitly and they must be attainable. To implement the process, knowledgeable, dedicated people must be assigned the task. Adequate training and constant feedback mechanisms are critical aspects to a successful monitoring program as tenable conclusions can be based only on reliable data.

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D. ACTIVITY-SPECIFIC RESEARCH

The primary objectives of our proposed research program are to (1) enhance understanding of Mexican spotted owl biology and (2) assess how land management practices affect the owl population's viability. These types of information are necessary to complement recovery efforts outlined in this plan. The research program described here is different from the monitoring program outlined in III.C. Whereas both programs are necessary, specific research needs may or may not be related to monitoring. In developing this chapter, we realized that readers of this plan have a variety of backgrounds. Thus, to establish a common framework for the discussion of a research program for the Mexican spotted owl, we first outline the role of the scientific process in research and some important aspects of study design. We then discuss some limitations with previous research, and suggest future research questions and processes that should be examined.

ROLE OF THE SCIENTIFIC PROCESS

Research and the reliability of knowledge gained from research depend on appropriate application of the scientific method. Reliable knowledge can be defined as "the set of ideas that agree or are consistent with the facts of nature," whereas "unreliable knowledge is the set of false ideas mistaken for knowledge" (Romesburg 1981). Three primary scientific methods have been used in scientific research (Romesburg 1981): (1) *induction* that involves the use of repeated observations to discover laws of association; (2) *retroduction* where a "best-guess" hypothesis is developed to explain a law of association or some set of observations; and (3) *hypothetico-deductive* (HD) where *a priori* hypotheses are developed and tested, and a decision made about whether to reject the hypotheses. It is generally accepted in science that application of the HD method provides the best avenue for gaining reliable knowledge (Platt 1964, Popper 1965, Romesburg 1981, 1991). Steps used in the HD method can be reiterated as follows from Nichols (1991): "(1) suggest a hypothesis to explain some phenomenon of interest, (2) deduce a testable prediction from that hypothesis, (3) devise and carry out a suitable test, and (4) use observations from the test to decide whether the prediction is met." When observations and predictions match, the hypothesis is corroborated; when they do not match, the hypothesis has been falsified and can be discarded. Rejection of hypotheses is key to the HD method. Corroboration of hypotheses can result from poor experimental designs (e.g., low power). Therefore, knowledge in the HD method is gained more through falsification of hypotheses than through corroboration.

Most research related to natural resource management and conservation has relied primarily on induction and retroduction (Romesburg 1981, 1991). Induction can provide us with reliable knowledge about associations such as the association of Mexican spotted owls with forests having certain structural characteristics. However, this method does not provide the mechanism for understanding the processes that underlie this association nor does it provide reliable knowledge about cause and effect. Whereas we can describe the structure of forests used by spotted owls, we cannot ascertain which structural characteristics are "important," or why, without application of the HD method. In short, we can describe patterns through induction but need the HD method to understand why those patterns occur and which components of those patterns are "important." In terms of management, understanding why a pattern has occurred and what caused it are important for predicting effects when observed patterns are changed.

Romesburg (1981) argued that retroduction does not provide reliable knowledge because of the inability of this method to falsify hypotheses and the large number of alternative hypotheses that could equally explain the same conclusions. However, both induction and retroduction are useful for describing relationships and develop-

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ing hypotheses to be further tested using the HD method. Unreliability of retroduction can be exacerbated when untested hypotheses are integrated into our knowledge base as dogma in the form of scientific "rules."

While induction and the HD method provide a general framework for gaining reliable knowledge, design of appropriate studies is crucial to the application of this method in specific situations. This applies to both describing and understanding patterns in nature. Any management plan, including the Mexican Spotted Owl Recovery Plan, is a complex hypothesis whose rejection or corroboration is determined by the success or failure of the plan over the long term.

IMPORTANT ASPECTS OF EXPERIMENTAL DESIGN

The ability to confidently infer results from a sample to a population of interest and the strength of that inference are entirely dependent on study design. Reliability of knowledge and the ability to make correct inferences are directly proportional; the stronger the inference one can make, the more reliable the knowledge stemming from that inference. The strongest inference in understanding patterns is achieved through controlled experiments, with the strength of inference diminishing the further a given study design departs from the experimental (HD) approach. However, inferences can be weakened even in experimental studies if the design is not valid. With Mexican spotted owls, we would like to extend inferences to a larger population than the one from which we sampled. This larger population may be across the range of the owl, within a certain recovery unit, or on a Ranger District within a National Forest. The ability to extend conclusions from a study to a larger area or a longer time period depends directly on how the study was designed and implemented.

For our purposes, study designs can be characterized as either descriptive or experimental (following Eberhardt and Thomas 1991). Descriptive studies employ survey sampling, whereas experimental studies use treatment and control groups. Necessary components of the design in both cases include: (1) *randomization* where samples are randomly selected in a descriptive study, or treatments and controls are randomly assigned in an experiment; and (2) *replication* of experimental units through both space and time. Randomization removes subjective biases that may be found in descriptive studies and guards against systematic differences other than treatment effects in experiments. Randomization also allows for stronger inference to a larger population and is the theoretical basis for employing statistical tests. Replication allows for estimation of experimental error, a prerequisite for employing statistical tests. If either randomization or replication are omitted from an experimental design, inferences will be greatly weakened. True replication should not be confused with "pseudoreplication" where subsampling of experimental units is confused with replication of experimental units (Hurlbert 1984). For example, a habitat study that measures 100 vegetation plots within each of four owl home ranges represents a sample of four, not 400. Frequently, researchers are guilty of pseudoreplication by reporting a sample size of 400. Inferences from such a study apply only to the 4 owls studied and not to a larger population. Thus, adequate replication must occur at the level of the experimental unit (in this case, number of home ranges) to apply to a larger population.

A major difficulty in doing field experiments is that they are performed in an uncontrolled, "noisy" environment (Eberhardt and Thomas 1991). Therefore, pre- and post-treatment measurement periods in both control and treatment groups are needed to reduce the effects of external variation and to ensure that a treatment effect can be adequately measured. Additional important design features necessary in field experiments include the choice of experimental units (e.g., owls, owl sites), local control (amount of balancing and blocking of experimental units), and the choice of the design (e.g., complete block, incomplete block, factorial).

An important consideration when designing and implementing studies that involve testing statistical hypotheses is the power of the statistical test used (the probability of rejecting the null hypothesis when it is false). Failure to reject a null hypothesis is due to either (1) the null hypothesis was indeed "true" or (2) there was insufficient power to reject it. Thus, power should be as high as possible (>90%) to corroborate that an unfalsified null hypothesis was actually not false. Power is dependent on a combination of the severity of the treatment applied, sample size, and experimental error. If a treatment is subtle, then a larger sample will be necessary to achieve the same power as if a severe treatment was used. This is important because biological questions often involve chronic (subtle) effects rather than acute (severe) effects. For example, the effects of a given land management practice may have a slight effect on adult survival rates which may in turn have strong effects on population viability. If an experiment testing such an effect has low power, then it may be tempting to state that the practice does not significantly affect survival rates when in fact it does. Repercussions from an experiment lacking sufficient power would then be misleading and result in false confidence in the health of the population.

LIMITATIONS IN PAST RESEARCH ON THE MEXICAN SPOTTED OWL

Previous research on Mexican spotted owls has been largely descriptive and has relied on induction and retroduction; our current knowledge concerning underlying ecological processes is, therefore, limited. However, previous research on Mexican spotted owls has provided a good foundation to describe the natural history of the species and to generate hypotheses for experimental tests with the HD method. Additional limitations on conclusions from previous research result from (1) lack of randomization in selecting experimental units and study areas, (2) lack of true replication (including small sample sizes), and (3) lack of experiments. The following discussion is not meant as criticism of specific research studies or scientists. Many of the previous studies have been hampered by inadequate funding and logistical constraints beyond the investigators' control. These factors are not unique to research on the Mexican spotted owl; they are common to research on numerous species, including both the northern and California spotted owls.

Lack of randomization and replication has hampered the ability to infer from particular samples to the general. In a number of studies, pseudoreplication has also been confused with true replication, weakening inferences even further. For example, most of the habitat studies using radiotelemetry have suffered from pseudoreplication. These studies typically sampled few (4-10) birds, but sampled habitat characteristics within these few birds' home ranges extensively. In testing hypotheses, the number of subsamples were used, rather than the number of owls, to estimate error terms used in statistical tests. Such pseudoreplication lends an incorrect perception of adequate power to statistical tests which may lead to incorrect conclusions. However, repetition of home-range studies over additional areas has strengthened inferences concerning certain habitat associations.

Controlled experiments have not been used in research on Mexican spotted owls. Lack of experiments is probably related to the need to quickly identify basic aspects of spotted owl natural history and apply this information to management situations. However, experiments are critical for defining the impacts of current and proposed management activities on Mexican spotted owls.

RESEARCH NEEDS

Several management issues and questions must be resolved to better understand and implement recovery measures for the Mexican spotted owl. Communication and collaboration between people with strong research skills and people with strong management skills will be a key component in this process. Managers need to better understand the methods, problems and uncertainties involved with research. Researchers, on the other hand, must rely on managers to identify appropriate questions, political and legal constraints, and to develop appropriate implementation of knowledge derived from research results. Too often researchers design and implement studies that do not adequately address management problems. People having both research and management skills will hopefully bridge the gap between management and research disciplines. Both time and money are short. Clearly, all research questions cannot be answered within a short time frame. Therefore, we advocate that a series of crucial experiments be implemented that address questions most relevant to the needs of management agencies. The following example of such an experiment addresses the question, "what structural features in forest habitat are needed to maintain high fitness in Mexican spotted owls," where fitness is some function of survival and reproduction:

- Determine appropriate statistical hypotheses (predictions) and response variables to be tested. Testing fitness directly through survival and reproductive rates may not be feasible because of the prohibitively large samples needed to detect chronic effects and ethical problems in purposely affecting survival of the owls. However, appropriate hypotheses from the initial question is that decline in foraging use and prey availability in altered habitats would directly affect fitness.

- Determine the extent and magnitude of treatments to apply to forested habitat. For example, testable research hypotheses could be that the extent of large trees in sites affects foraging use by owls and prey abundance. Treatments may be nested so that the same experimental units can be used in repeated experiments, assuming that treatments can be decided upon beforehand and applied consecutively. In addition, treatments need not be "negative" by removing habitat components but can be "positive" by treating previously impacted habitats. Thus, careful planning is needed at this stage.

- Randomly select *n* spotted owl sites so that sufficient power can be achieved to detect differences in foraging by owls between treatments. Attach radio-transmitters to owls within sites.

- Collect pre-treatment data and define high-use areas by owls within all sites.

- Randomly assign treatment and control classifications to the *n* owl sites.

- Apply the treatment to high-use foraging areas within treatment sites only.

- Collect post-treatment data.

- Test for differences between treatment and control groups.

- Continue the same procedure with additional treatments.

While not ideal, such an experiment illustrates the principles of scientific experimental design necessary to achieve reliable knowledge concerning spotted owl habitat use and, indirectly, fitness, as a function of forest structure. Such crucial experiments are difficult to design, require commitments of funding, and scientific imagination because of ethical constraints and the limitations on allowable habitat alterations proposed in this plan. However, these types of experiments also more rapidly answer pressing management questions.

We recommend research on the following questions about Mexican spotted owls that still need answers. Clearly, a large number of research questions could be developed that address all aspects of Mexican spotted owl biology for which knowledge is lacking. However, we pose what we believe are the most crucial questions that need to be addressed in terms of immediate management problems and the recovery of the owl. Studies designed to answer these questions will be descriptive, experimental, or a combination of both.

Dispersal

Dispersal is a key process in metapopulation theory and to maintain genetic diversity between isolated subpopulations (Keitt et al. 1995). Key questions include:

- Are subpopulations within and between Recovery Units connected?
- What habitats and large-scale habitat configurations do dispersing juveniles require to maintain adequate survival rates during dispersal?

Genetics

Mexican spotted owl populations are naturally fragmented across their range. Genetics can provide insight into historical connections between subpopulations. Therefore, questions on genetics also relate to dispersal. Key questions include:

- Are subpopulations within and between Recovery Units genetically isolated and to what degree?
- What is the extent of genetic interchange across the entire range of the owl?

Habitat

Mexican spotted owls use a variety of habitats ranging from canyons to forested areas (Ganey and Dick 1995). Key questions include:

- To what extent is habitat use determined by various factors, such as prey availability, temperature regulation, and/or avoidance of predators?
- What habitat components confer high fitness?
- How do land management activities, specifically grazing, timber harvest, fire, and recreation use, proximately affect habitat use and ultimately affect fitness?

Population Biology

Currently, little is known about Mexican spotted owl populations. Key questions can be addressed with our proposed monitoring plan:

- Is the Mexican spotted owl population stable, increasing, or declining?
- Are some subpopulations increasing while others are decreasing within the range of the owl?

Threats to Recovery

Perceived threats need to be examined in relation to current management strategies to examine whether these strategies are appropriate and to develop appropriate management strategies. Key questions include:

- What management strategies can be employed to reduce to possibility of catastrophic loss of owl habitat by fire while maintaining important habitat components?
- To what extent does disturbance from recreation, vehicles, etc. affect use of sites by spotted owls?
- How does grazing affect prey abundance in habitats used by spotted owls for foraging?

Other Ecosystem Components

Implementation of the recovery measures for the Mexican spotted owls will directly and indirectly affect numerous ecosystem attributes. Research is needed to determine the extent of these effects on biotic and abiotic components, and ecosystem processes and function. Key questions are:

- What are the effects of this recovery plan on other vertebrates?
- What are the effects of implementing the Plan on nonvertebrates?
- What are the effects of implementing the Recovery Plan on plant community structure and composition?
- What are the effects of implementing the Recovery Plan on abiotic ecosystem processes (e.g., hydrological systems)?
- What are the effects of implementing the plan on ecosystem structure and function?
- How might the recovery plan be adjusted to mitigate potentially deleterious effects on other ecosystem attributes?

E. SUMMARY OF RECOVERY

The ultimate goal of this Recovery Plan is to "recover" the Mexican spotted owl from threatened status. This action is referred to as "delisting" and is governed by section 4 of the Act. Delisting the Mexican spotted owl will require reexamination of the same five factors considered during every listing process. In addition, five specific criteria have been developed to aid the delisting determination. Three of these criteria pertain to the entire range of the owl and two refer to a recovery unit level. The rangewide delisting criteria are:

1. The populations in the Upper Gila Mountains, Basin and Range-East, and Basin and Range - West RUs must be shown to be stable or increasing after 10 years of monitoring, using a study design with a power of 90% to detect a 20% decline with a Type I error rate of 0.05.

2. Scientifically-valid habitat monitoring protocols are designed and implemented to assess (a) gross changes in habitat quantity across the range of the Mexican spotted owl, and (b) whether microhabitat modifications and trajectories within treated stands meet the intent of the Recovery Plan.

3. A long-term, U.S.-rangewide management plan is in place to ensure appropriate management of the subspecies and adequate regulation of human activity over time.

Once the above three criteria are met, delisting may occur in any RU that meets the final two criteria:

4. Threats to the Mexican spotted owl within the RU are sufficiently moderated and/or regulated.

5. Habitat of a quality to sustain persistent Mexican spotted owl populations is stable or increasing within the RU.

Recovery of the Mexican spotted owl hinges on successful implementation of three interrelated programs: population and habitat monitoring, management guidelines, and research. These aspects are not intended to stand alone; thus, all programs must be implemented simultaneously. For example, monitoring provides a measure of the effectiveness of the management guidelines. Without such monitoring, we will have no basis for determining whether management guidelines lead to the desired outcomes, and thus whether the bird should be delisted. Research is needed to answer key questions relevant to the Mexican spotted owl, particularly how implementation of management recommendations will affect the Mexican spotted owl and its habitat. The knowledge derived from this research will provide a scientific basis for revising short-term guidelines and developing a long-term management plan.

We have proposed a quadrat sampling scheme and provide detailed considerations for determining spotted owl population trends within the Upper Gila Mountains, Basin and Range - East, and Basin and Range - West RUs. Population monitoring is not required for other recovery units because of sampling constraints posed by smaller population sizes. The suggested scheme provides a statistically valid means for assessing population change Initial cost estimates for the owl monitoring scheme will range from $1.2 to $1.5 million per year.

Habitat monitoring is needed to estimate trends in the quantity and quality of the owl's habitat through time. Rangewide monitoring of the owl's habitat should be conducted in conjunction with population monitoring. Because of the areal extent over which monitoring will be required, we propose the use of satellite imagery for tracking gross losses in habitat. We also propose that field sampling be conducted in conjunction with planned management treatments. Treatments include the use [illegible]ribed fire, thinning, and silviculture. Monitoring should be done prior to and immediately following the treatment, and then at five-year intervals. The objective of this sampling is to determine changes in microhabitat features and also to verify that vegetation was placed or continues on a trajectory to become replacement habitat.

Threats to be moderated include those that need site-specific treatment to alleviate them such as the reduction of the risks of catastrophic fire. For threats to be considered moderated, reasonable progress must have been made to remove identified threats and there must be adequate assurance that management programs will continue. Long-term management plans are needed to guide management after the bird is delisted. Threats to be regulated include those resulting from agency management programs or other anthropogenic activities that are either ongoing or reasonably certain to occur. These types of threats include wildfire hazard, timber harvest, urban or rural land development, grazing, and recreation.

A primary focus of this Recovery Plan is to provide recommendations that will moderate or regulate threats over the short term (10-15 years). Conceptually, this requires the presence of a mosaic of successional stages throughout a landscape comprised of the different habitats used by Mexican spotted owls. The arrangement and diversity of these habitats must promote the owl's persistence. The short-term strategy is aimed at protecting existing owl habitat and initiating a process to develop replacement habitat. Although the approach is not completely synonymous with ecosystem management, implementation of the recommendations should sustain biotic diversity and natural processes by managing several forest and woodland systems used by the owl. Recommendations include management of mixed-conifer and pine-oak forests, and riparian areas. Ponderosa pine and spruce-fir forests are also considered to a limited degree.

Several potential threats to the owl were identified by examining the best available information on the owl's biology, and by evaluating ecological disturbance patterns and current conditions throughout the owl's range. Primary threats include catastrophic fire, timber and fuelwood harvest, grazing, and recreation. The magnitude of a threat's influence on the owl can vary according to temporal and spatial setting. For this reason, general recommendations were developed by habitat type which apply throughout the owl's range, and are emphasized according to the magnitude of the threats within each RU. The recommendations were also designed to provide different levels of protection depending on the owl's use of a particular habitat, the nature of the threats, and management potential. Our intent was to offer the most specific recommendations that the best available information would permit while allowing land managers flexibility for implementing the recommendations.

Three areas of management are provided under the general recommendations: protected areas, restricted areas, and other forest and woodland types. Protected areas receive the highest level of protection. Recovery plan guidelines take precedence over other management guidelines in protected areas. Guidelines for restricted areas are less specific and operate in conjunction with existing management guidelines. Specific guidelines are not proposed for other forest and woodland types.

Protected areas are all occupied nest or roost areas, all areas with slope >40% where timber harvest has not occurred in the past 20 years, and all legally administered reserved lands. Protection of owl nest and roost areas will be established by designating an area of protection around an activity center (PAC). This will require (1) inventory of spotted owls before planning any management activity that will alter stand structure; (2) delineating PAC areas of 243 ha (600 ac) for all known Mexican spotted owl sites, including sites located prior to proposed management activities; and (3) light burning in PACs if considered necessary and prudent to reduce risk of catastrophic loss. Further, a fire abatement program is proposed to allow treatment of small fuels within PACs and minimize probabilities of catastrophic fire. The purpose of PACs is to provide refugia habitat until it can be demonstrated reliably that owl habitat can be created through management. In addition, harvest of trees >22.5 cm (9 inches) dbh is not allowed on slopes >40% where timber harvest has not occurred in the past 20 years. However, light burning and prescribed natural fire management is permitted. Prescribed natural fire is

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also encouraged on reserved lands (e.g., wilderness, Research Natural Areas) where appropriate.

We recommend that management activities be restricted on some lands outside of protected areas because patterns of owl use can be expected to change over time. The guidelines depend upon forest or woodland type. Silvicultural prescriptions should emphasize measures to place stand conditions on a trajectory to become owl habitat where appropriate. Stands that currently meet or exceed threshold conditions are subject to more stringent restrictions than other stands. Specific management prescriptions should be site specific and will vary according to short- or long-term objectives.

Short-term guidelines should not be misconstrued as onetime management events. For example, large trees and snags are used by the spotted owl and will continue to be needed beyond the life of the plan. Long-term guidelines are recommended for those activities and natural processes that combine to influence the owl and its habitat beyond the life expectancy of this Recovery Plan.

In addition, riparian communities should be managed by maintaining broad-leaved forests in healthy condition where they occur, especially in canyon-bottoms. Restoration may be necessary where such forests are not regenerating adequately. Conceivably, restored riparian forests could contribute additional nesting, wintering and dispersal habitat in the future. A mix of plant size and age classes should be emphasized in this community, to include large mature trees, vertical diversity, and other structural characteristics.

No specific guidelines are recommended in forest or woodland types not typically used by the owl for nesting. These include ponderosa pine, spruce-fir, pinyon-juniper, and quaking aspen in areas outside of PACs. However, some relevant management of these communities may produce desirable results for owl recovery. Examples of guidelines include managing for landscape diversity, mimicking natural disturbance patterns, incorporating natural variation in stand conditions, retaining special features such as snags, and utilizing fire in an appropriate manner.

Livestock and wildlife grazing may influence spotted owls by altering (1) prey availability, (2) fire risk of some habitats, (3) riparian plant communities, and (4) development of spotted owl habitat. The Team strongly advocates field monitoring and experimental research related to impacts of grazing on the Mexican spotted owl. Other specific guidelines include (1) monitoring grazing use by livestock and key wildlife species (e.g. elk, deer), (2) implementing and enforcing grazing utilization standards that attain good to excellent range use standards, and (3) protecting or restoring riparian communities. These guidelines are emphasized in protected, restricted, and riparian areas.

Several guidelines for managing recreation in protected, restricted, and riparian areas are recommended. These include: (1) no construction, either of new facilities or for expanding existing facilities, is allowed within PACs during the breeding season; (2) construction during the nonbreeding season should be considered on a case-specific basis; (3) managers should, on a case-specific basis, assess the presence and intensity of allowable recreational activities within PACs; and (4) seasonal closures of specifically designated recreation activities should be considered in extreme circumstances.

Several important questions regarding the owl's ecology, and in particular about the effects of different management activities on the owl's population viability, still remain. The Team recommends additional research on Mexican spotted owl dispersal, genetics, habitat ecology, and population biology. Key information that is vital for refining recovery strategies include (1) the degree of demographic and genetic isolation among subpopulations; (2) the relationship between fitness and specific habitat components; (3) population trend. Communication and collaboration between researchers and managers will be paramount for obtaining necessary information.

This Recovery Plan presents realistic goals for recovery of the Mexican spotted owl and its ultimate delisting. The goals are flexible in that they allow local land managers to make site-specific decisions about management for recovery. The success of the recovery process hinges on commitment and coordination among Federal and State land management agencies, sovereign Indian Nations, and the private sector to ensure that the plan is followed and executed as intended by the Team.

Recovery Plan Implementation

Volume I, Part IV

A. IMPLEMENTING LAWS, REGULATIONS, AND AUTHORITIES

Part IV discusses laws, regulations, policies, and authorities directly relevant to implementing the recovery recommendations included in Part III. An approach to implementation oversight is also recommended. Finally, a stepdown outline of recovery tasks and an implementation schedule are provided.

This Mexican Spotted Owl Recovery Plan is based or predicated upon laws that designate specific legal authority and responsibility to government agencies for managing public resources, including wildlife and wildlife habitat. The following summarizes relevant laws and authorities applicable to implementation of this Recovery Plan.

ENDANGERED SPECIES ACT

Section 2(c)(2) of the Act expresses the policy of Congress that "...all Federal departments and agencies shall seek to conserve endangered species and threatened species and shall utilize their authorities in furtherance of the purposes of [the] Act." Section 7(a)(1) of the Act requires Federal agencies to "...utilize their authorities in furtherance of the purposes of the Act by carrying out programs for the conservation of endangered species and threatened species...." Thus, Congress clearly intended conservation of endangered and threatened species to be considered in implementation of Federal programs and actions. In addition, other Federal laws and regulations require consideration of endangered and threatened species in program implementation, including the National Forest Management Act (NFMA) and the National Environmental Policy Act (NEPA).

Implementation of the Act is the responsibility of the Secretary of the Interior for listed terrestrial species. The Secretary generally delegates implementation authority to the FWS. The following sections of the Act are relevant to implementation of species recovery efforts:

Section 4

Section 4 includes the listing and recovery provisions of the Act, which are discussed in detail in Part I. Section 4(b) of the Act provides for designation of critical habitat for endangered and threatened species. Regulations governing critical habitat designation are codified at 50 CFR 424. Protection of critical habitat is administered under section 7 of the Act (discussed below). Critical habitat is defined under section 3(5)(A) of the Act as:

> "(i) the specific areas within the geographical area occupied by the species...on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and
>
> (ii) specific areas outside the geographical area occupied by the species...upon a determination by the Secretary that such areas are essential for the conservation of the species."

Section 4(d) of the Act provides for promulgation of special rules for threatened species only. This allows the Secretary to issue regulations as deemed necessary for the conservation of such species. Special rules can be useful in enacting regulatory provisions uniquely applicable to the species at hand, and can be promulgated to avoid unnecessary regulatory burden. For example, the FWS is considering a special 4(d) rule to allow small landowners in the Pacific Northwest to harvest timber and conduct other activities without risk of violating the prohibition of incidentally taking (see definition under Section 9, below) northern spotted owls.

Section 5

Section 5 directs the Secretary to utilize funds and authorities of other laws in acquisition of lands, as deemed appropriate for conservation of endangered and threatened species.

Section 6

This section authorizes cooperation with the States in conservation of threatened and endangered species. Among its provisions is the authority to enter into management agreements and cooperative agreements and to allocate funds to the States that have entered into such agreements.

Section 7

Section 7 and its implementing regulations at 50 CFR 402 govern cooperation between Federal agencies. Federal agencies must, in consultation with and with the assistance of the Secretary, ensure that any action they fund, authorize, or carry out is not likely to jeopardize the continued existence of listed species or result in the destruction or adverse modification of a listed species' designated critical habitat. Regulations at 50 CFR 402 provide the following definitions:

> "'Jeopardize the continued existence of' means to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species."

> "'Destruction or adverse modification' means a direct or indirect alteration that appreciably diminishes the value of critical habitat for both the survival and recovery of a listed species."

Section 7 requires action agencies to assess the effects of proposed actions on listed species and their critical habitat. If, as a result of that assessment, the agency determines that an action may affect a listed species or its critical habitat, the agency must enter into consultation with the FWS. That consultation may result in a biological opinion from the FWS, in which a determination is made as to whether jeopardy to the species and/or destruction or adverse modification of its critical habitat are likely to result from the agency action.

If a biological opinion concludes that jeopardy to the species and/or adverse modification of its critical habitat are not likely to result from a proposed action, the action may proceed. The FWS may provide conservation recommendations to the agency on ways to minimize or avoid potential adverse effects on listed species and/or critical habitat. Implementation of these conservation recommendations is at the action agencies' discretion. In cases where the action is likely to result in the incidental taking of a species (see definition under "Section 9," below), the Service may provide reasonable and prudent measures to minimize the amount or extent of incidental take. The terms and conditions that accompany and implement any reasonable and prudent measures are nondiscretionary and must be implemented. However, reasonable and prudent measures and their implementing terms and conditions cannot alter the basic design, location, scope, duration, or timing of the action; and they may involve only minor changes.

If a biological opinion determines that jeopardy and/or adverse modification is likely to result from a proposed action, the FWS and the action agency develop reasonable and prudent alternatives, if any, to the proposed action. Reasonable and prudent alternatives refer to alternative actions that are consistent with the intended purpose of the proposed action, that can be implemented within the action agency's legal authority, that are economically and technologically feasible, and that the FWS believes will not result in jeopardy to listed species or destruction or adverse modification of critical habitat. If no reasonable or prudent alternatives can be identified, the action agency may apply to the Endangered Species Committee for an exemption to the prohibition of jeopardy and/or destruction or adverse modification of critical habitat.

Section 8

Section 8 authorizes international cooperation in conservation of endangered and threatened species. Included under this section is the authority to provide financial assistance to foreign countries to assist in their conservation efforts.

Section 9

Section 9 covers prohibited acts in regard to listed species. Of relevance to the Mexican spotted owl is the prohibition of taking individuals. "Take" is defined as "...to harass, harm, pursue, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." Permits for direct taking of threatened species may be issued for scientific purposes, to enhance propagation or survival, in cases of economic hardship, for zoological exhibition, or for educational purposes (50 CFR 17.32).

Taking of spotted owls is most likely to occur through "incidental take." "Incidental take" is defined as taking that results from, but is not the purpose of, carrying out an otherwise lawful activity. Incidental taking of spotted owls may result from such activities as timber harvest, if that activity results in habitat loss to an extent that an individual spotted owl's normal behavior patterns are impaired. In cases where incidental taking will not result in jeopardy to a listed species, the FWS may issue an incidental take statement in a biological opinion on a proposed Federal action, thereby removing the take prohibition. Relief from the taking prohibition for non-Federal activities is discussed under "section 10" below.

Section 10

Section 10 authorizes the FWS to issue permits for takings otherwise prohibited under section 9. Such permits may be issued for research purposes and the other situations described above. In addition, section 10(a)(1)(B) allows permits for incidental taking that may result from an activity, provided an applicant submits a conservation plan that specifies:

> "(i) the impact which will likely result from such taking;
>
> (ii) what steps the applicant will take to minimize and mitigate such impacts, and the funding that will be available to implement such steps;
>
> (iii) what alternative actions to such taking the applicant considered and the reasons why such alternatives are not being utilized; and
>
> (iv) such other measures that the [FWS] may require as being necessary or appropriate for purposes of the plan."

NATIONAL FOREST MANAGEMENT ACT

The NFMA governs Forest Service Management on National Forest System lands. Section 219.19 (Fish and wildlife resources) states:

> "Fish and wildlife habitat shall be managed to maintain viable populations of existing native and desired nonnative vertebrate species in the planning area. For planning purposes, a viable population shall be regarded as one which has the estimated numbers and distribution of reproductive individuals to ensure its continued existence is well distributed in the planning area. In order to ensure that viable populations will be maintained, habitat must be provided to support, at least, a minimum number of reproductive individuals and that habitat must be well distributed so that those individuals can interact with others in the planning area."

In formulating alternatives during project planning, the following is required in regard to fish and wildlife habitat:

"Each alternative shall establish objectives for the maintenance and improvement of habitat for management indicator species...to the degree consistent with overall multiple-use objectives of the alternative. To meet this goal, management planning for the fish and wildlife resources shall meet the requirements set forth [as follows:]

(1) In order to estimate the effects of each alternative on fish and wildlife populations, certain vertebrate and/or invertebrate species present in the area shall be identified and selected as management indicator species and the reasons for their selection will be stated. These species shall be selected because their population changes are believed to indicate the effects of management activities. In the selection of management indicator species, the following categories shall be represented where appropriate:

- Endangered and threatened plant and animal species identified on State and Federal lists for the planning area;
- Species with special habitat needs that may be influenced significantly by planned management programs;
- Species commonly hunted, fished, or trapped;
- Nongame species of special interest; and
- Additional plant or animal species selected because their population changes are believed to indicate the effects of management activities on other species of selected major biological communities or on water quality.

"On the basis of available scientific information, the interdisciplinary team shall estimate the effects of changes in vegetation type, timber age classes, community composition, rotation age, and year-long suitability of habitat related to mobility of management indicator species. Where appropriate, measures to mitigate adverse effects shall be prescribed.

(2) Planning alternatives shall be stated and evaluated in terms of both amount and quality of habitat and of animal population trends of the management indicator species.

(3) Biologists from State fish and wildlife agencies and other Federal agencies shall be consulted in order to coordinate planning for fish and wildlife, including opportunities for the reintroduction of extirpated species.

(4) Access and dispersal problems of hunting, fishing, and other visitor uses shall be considered.

(5) The effects of pest and fire management on fish and wildlife populations shall be considered.

(6) Population trends of the management indicator species will be monitored and relationships to habitat changes determined. This monitoring will be done in cooperation with State fish and wildlife agencies, to the extent practicable.

(7) Habitat determined to be critical for threatened and endangered species shall be identified, and measures shall be prescribed to prevent the destruction or adverse modification of such habitat. Objectives shall be determined for threatened and endangered species that shall provide for, where possible, their removal from listing as threatened and endangered species through appropriate conservation measures, including the designation of special areas to meet the protection and management needs of such species."

NATIONAL ENVIRONMENTAL POLICY ACT

The NEPA requires Federal agencies to prepare Environmental Impact Statements (EIS) or Environmental Assessments (EA) for implementation of agency actions and issuance or modification of agency policies and guidance. Impacts of the proposed action or policy amendment on endangered and threatened species must be evaluated. If a deciding official determines that no significant impact will result from an action or policy amendment, a Finding of No Significant Impact is issued. If an agency determines that a significant impact will result from the proposed action or policy amendment, an EIS must be prepared. An EIS addresses a range of alternatives. It is released for public review and comment, after which an alternative is selected and a Record of Decision is signed by the deciding official.

MIGRATORY BIRD TREATY ACT

Prior to listing the Mexican spotted owl as threatened, the Migratory Bird Treaty Act (MBTA) provided the only Federal protection for the subspecies other than that afforded by land-management agencies. Under the provisions of the MBTA, it is unlawful to pursue, hunt, take, capture, or kill in any manner any migratory bird unless permitted by regulations. The MBTA applies in both the U.S. and Mexico. Because the Mexican spotted owl exhibits migratory behavior in some areas it is included on the list of birds protected under the MBTA.

TRIBAL LANDS

The Recovery Team encourages adoption of the recovery recommendations by all Tribes administering lands that support Mexican spotted owl habitat. Tribal land-management regulations and programs, including those for conservation of species, typically require enactment by Tribal Councils.

STATE AND PRIVATE LANDS

Although relatively few Mexican spotted owls are known on State and private lands, the Team recommends that States continue and/or begin a program to inventory forested areas for the presence of Mexican spotted owls. The Recovery Team is unaware of any State laws or regulations that govern management of spotted owl habitat on State or private lands. The Recovery Team recommends incorporating the recovery recommendations into State wildlife and forest practices laws and regulations. In addition, the Recovery Team encourages the FWS to evaluate the importance of State and private lands to the Mexican spotted owl, and to consider promulgating a special rule under section 4(d) of the Act that specifies habitat-altering activities that can be allowed on private lands without violating the prohibition of incidentally taking Mexican spotted owls.

MEXICO

The Recovery Team is unfamiliar with the laws, regulations, and authorities that are available or appropriate for implementing the recovery recommendations in Mexico. As recommended later in Part IV, the Recovery Team expects the FWS to arrange a meeting with Mexican officials to discuss the Recovery Plan and its implementation.

B. IMPLEMENTATION OVERSIGHT

RECOVERY UNIT WORKING TEAMS

The Team strongly recommends formation of interagency working teams whose responsibility would be to oversee the implementation of the Recovery Plan. These Recovery Unit Working Teams would coordinate with and report to the Recovery Team, which would evaluate any Working Team recommendations before passing them on to the FWS. Working Teams for each U.S. Recovery Unit should be appointed by the FWS as subunits under the Recovery Team umbrella. Recovery Team members may also serve on Recovery Unit Working Teams if that arrangement is agreeable. Membership of the Working Teams should include, at a minimum, one representative from each of the following:

1. Each involved FWS Ecological Services Field Office
2. Each involved FS Region
3. Each involved State
4. Each involved Indian Reservation
5. Any other involved agency (e.g., BLM, NPS).

Each Working Team should have a research scientist among its membership. That person may be affiliated with one of the agencies listed above, or may be independent. In addition to the above, other interested persons approved by the Recovery Team and the FWS should be allowed to participate if they so request. Such participants may include a representative from a conservation organization, a representative from the timber or other affected industry, a representative from an interested county or other local government agency, and others as appropriate. Such a diverse membership would allow ideas of varying viewpoints to be discussed and would allow local interested parties to participate in plan implementation and resolution of local issues. Working Teams for each Mexican Recovery unit should be similarly composed.

Once the FWS formulates a membership list, that list should be submitted to the Recovery Team for review. The Recovery Team would then request the FWS's Southwest Regional Director's approval. Travel costs for each member would be borne by the member's agency or organization.

The functions of the Recovery Unit Working Teams should include the following:

1. Provide technical assistance to agencies and landowners on such issues as project designs, spotted owl management plan development, and Recovery Plan compliance. The Recovery Team strongly encourages conducting Recovery Plan implementation workshops to provide biologists, foresters, and other land-management personnel a common working knowledge of the provisions of this Recovery Plan. For example, a workshop to develop procedures for delineating PACs would encourage consistent application of recovery recommendations. Specific workshop recommendations are provided in IV.C.
2. Provide guidance and interpretation on implementation of the recommendations contained in this Recovery Plan.
3. Provide research assistance by procuring financial and logistic support, screening research proposals for importance and relevance, recommending to the Recovery Team prioritization of research proposals, and other functions.
4. Recommend Recovery Plan revisions based on research results that may enhance recovery efforts in that specific RU.

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5. Prioritize areas to be inventoried within the RU.

6. Promote communication between various local interests and help resolve conflicting interpretations of the Recovery Plan provisions.

7. Monitor plan implementation and report problems, successes, and general recovery progress to the FWS and the Recovery Team at least annually.

CONTINUING DUTIES OF THE RECOVERY TEAM

The Recovery Team recommends that it be continued throughout Recovery Plan implementation. Once the final Recovery Plan is complete, the Recovery Team should meet at least twice per year for the first two years and annually thereafter. The purpose of these meetings would be to hear and discuss plan implementation reports with the Recovery Unit Working Teams, and to report to the FWS on the progress of the recovery effort. The Team would also consider recommendations from Recovery Unit Working Teams and decide what recommendations should be brought forward to the FWS as potential revisions to the Recovery Plan.

CENTRALIZED SPOTTED OWL INFORMATION REPOSITORY

The Recovery Team recommends that a central Mexican spotted owl data facility be maintained throughout the life of the Recovery Plan. The main purpose of such a facility would be to house a spotted owl GIS database, including data assembled through the monitoring program, inventory program, and other programs recommended in this Recovery Plan. In addition, the facility would maintain and periodically update a Mexican spotted owl bibliography.

Such a facility would be a valuable resource for biologists, land managers, researchers, and others who may need information throughout the plan implementation period. Considerable information, assembled as a result of development of this plan, is already stored in a GIS system maintained by the National Biological Service's Midcontinent Ecological Science Center (formerly the National Ecology Research Center) in Fort Collins, Colorado; continuance of that arrangement is recommended by the Team. In addition, a considerable "Literature Cited" section is included in this plan, which should provide a good start to development of a Mexican spotted owl bibliography.

C. STEPDOWN OUTLINE

This section lists specific tasks that need to be implemented according to the recovery recommendations in Part III, plus Recovery Plan oversight provisions discussed earlier in Part IV. This list is in a stepdown format, as required in the FWS recovery planning guidelines. Each task is also listed in Table IV.D.1, where the responsible parties for task implementation and the estimated costs of carrying out the tasks are provided. Tasks are categorized as follows:

1. *Resource Management Programs.* Many of the recovery recommendations relate to spotted owl considerations that should be incorporated into planning for other resource management objectives such as timber harvest, recreation, and management of other species.

2. *Active Management.* These recovery tasks are to be implemented actively. They include forest health enhancement and protection, riparian restoration, and development of a long-term spotted owl management plan.

3. *Monitoring.* These recommendations relate to monitoring the spotted owl population and habitat.

4. *Research.* These recommendations include research studies designed to increase life-history knowledge of the subspecies and to test the effects of land management activities on spotted owls.

5. *Oversight, Review, Evaluation, and Revision.* These tasks are necessary to monitor the Recovery Plan's effectiveness and to determine if and when Recovery Plan revision is necessary.

1. Resource Management Programs

11. Incorporate recovery recommendations (Part III) into land management programs.

    111. Conduct the NEPA process to amend appropriate land management guidance and policy documents (Federal lands).

        1111. FS
        1112. BLM
        1113. NPS
        1114. DOD

    112. Incorporate recovery recommendations into Tribal management plans.

        1121. White Mountain Apache
        1122. Mescalero Apache
        1123. San Carlos Apache
        1124. Navajo
        1125. Other tribes

    113. Incorporate recovery recommendations into State regulations pertaining to timber harvests and other activities on State and private lands.

        1131. Arizona
        1132. New Mexico
        1133. Utah
        1134. Colorado

    114. Incorporate recovery recommendations into Mexican policy documents.

        1141. Arrange a meeting between FWS, Recovery Team, and Mexican representatives to discuss provisions of the Recovery Plan.

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1142. Conduct actions necessary to officially adopt Recovery Plan recommendations into Mexican law and/or policy, as appropriate.

12. Conduct pre-project Mexican spotted owl inventories in project areas.

    121. Federal agencies

        1211. FS
        1212. BLM
        1213. NPS
        1214. DOD

    122. Tribes

        1221. White Mountain Apache
        1222. Mescalero Apache
        1223. San Carlos Apache
        1224. Navajo
        1225. Other tribes

    123. States
        1231. Arizona
        1232. New Mexico
        1233. Utah
        1234. Colorado

    124. Mexico

2. Active Management

21. Develop and/or implement forest health improvement and protection programs.

    211. Federal lands

        2111. FS
        2112. BLM
        2113. NPS
        2114. DOD
        2115. Other Federal agencies

    212. Tribal lands

        2121. White Mountain Apache
        2122. Mescalero Apache
        2123. San Carlos Apache
        2124. Navajo
        2125. Other tribes

    213. State and private lands

        2131. Arizona
        2132. New Mexico
        2133. Utah
        2134. Colorado

    214. Mexico

22. Actively manage riparian habitat (e.g., restore degraded areas).

    221. Lowland riparian

        2211. BLM
        2212. State of Arizona
        2213. State of New Mexico
        2214. State of Utah
        2215. State of Colorado
        2216. Mexico

    222. Middle to upper elevation riparian

        2221. Federal lands

            22211. FS
            22212. BLM
            22213. NPS
            22214. DOD
            22215. Other Federal agencies

        2222. Tribes

            22221. White Mountain Apache
            22222. Mescalero Apache
            22223. San Carlos Apache
            22224. Navajo
            22225. Other tribes

        2223. Mexico

23. Develop and implement a long–term, range wide management plan.

- 231. Establish and support a Federal/Tribal/State/Mexican team to develop the plan.
- 232. Develop a draft management plan.
- 233. Conduct peer/public review.
- 234. Produce final management plan.
- 235. Develop appropriate implementation documents.
  - 2351. Joint Federal agency EIS
  - 2352. White Mountain Apache
  - 2353. Mescalero Apache
  - 2354. San Carlos Apache
  - 2355. Navajo
  - 2356. Other tribes
  - 2357. State MOUs
    - 23571. Arizona
    - 23572. New Mexico
    - 23573. Utah
    - 23574. Colorado
  - 2358. Mexico

3. Monitoring

31. Implement the population monitoring program detailed in Part III.

- 311. Secure funding for the entire monitoring period (up to 15 years).
- 312. Appoint a principle investigator.
- 313. Develop detailed study methodology/protocols.
- 314. Conduct Recovery Team/peer review of program.
- 315. Conduct a pilot study.
- 316. Evaluate and revise methodology/protocols.
- 317. Implement the monitoring program.

32. Implement the habitat monitoring program detailed in Part III.

- 321. Macrohabitat
  - 3211. Acquire appropriate remote sensing imagery.
  - 3212. Conduct necessary ground-truthing, imagery classification, geo-referencing, etc.
  - 3213. Acquire remote sensing imagery at year 5.
  - 3214. Conduct necessary ground-truthing, imager classification, geo-referencing, etc.
  - 3215. Conduct change-detection analysis.
  - 3216. Acquire remote sensing imagery at year 10.
  - 3217. Conduct necessary ground-truthing, imagery classification, geo-referencing, etc.
  - 3218. Conduct change-detection analysis.
- 322. Microhabitat (ongoing)
  - 3221. Take pre-treatment measurements of relevant habitat variables.
  - 3222. Design treatment(s) to accomplish spotted owl habitat or other ecosystem management goals.
  - 3223. Conduct treatment
  - 3224. Take post-treatment measurements at year 1 of important habitat variables.
  - 3225. Compare pre- and post-treatment data to determine whether objectives of treatment were met.
  - 3226. Measure habitat variables at year 5.
  - 3227. Determine whether treated stands are on appropriate trajectories.

4. Research

41. Implement the research recommendations outlined in Part III.

- 411. Conduct dispersal studies.

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4111. Examine connectivity of subpopulations within and between RU's.

4112. Determine habitat configurations that best facilitate dispersal and enhance survival rates of dispersing juveniles.

412. Conduct studies on genetics.

4121. Determine whether and to what degree subpopulations are genetically isolated.

4122. Determine the extent and patterns of gene flow across the landscape.

413. Conduct habitat studies.

4131. Study the extent to which habitat use is influenced by prey availability, microclimatic factors, or presence of predators.

4132. Determine which habitat components influence individual fitness and population persistence.

414. Study the effects of land-use practices on spotted owls and/or spotted owl habitat.

4141. Determine the effects of various silvicultural and timber–harvest practices on spotted owl habitat.

4142. Determine the effects of livestock and wildlife grazing on spotted owl habitat and prey.

4143. Determine the effects of prescribed fire on spotted owl habitat and prey.

4144. Determine the effects of recreational activities on spotted owl habitat.

415. Study the effects of human disturbance on spotted owls.

4151. Determine the effects of noise-producing activities on nesting spotted owls.

4152. Determine the effects of suburban and rural development on habitats and populations of spotted owls.

416. Study the effects of Recovery Plan implementation on other ecosystem components.

4161. Vertebrates and vertebrate communities

4162. Invertebrates and invertebrate communities

4163. Plants and plant communities

4164. Abiotic features (e.g. hydrological systems)

4165. Ecosystem structure and functioning

42. Conduct general inventories in areas that have not previously been inventoried for spotted owls.

421. Federal lands

4211. FS
4212. BLM
4213. NPS
4214. DOD
4215. Other Federal agencies

422. Tribal lands

4221. White Mountain Apache
4222. Mescalero Apache
4223. San Carlos Apache
4224. Navajo
4225. Other tribes

423. State and private lands

4231. Arizona
4232. New Mexico

4233. Utah

4234. Colorado

424. Mexico

43. Maintain a centralized Mexican spotted owl information facility.

431. Establish and maintain a Mexican spotted owl GIS database.

4311. Establish and annually update spotted owl location records and inventory coverages.

4312. Establish and periodically update spotted owl habitat coverages at varying spatial scales.

432. Develop and periodically update a spotted owl bibliography.

433. Distribute information to land mangers and others who request it.

5. Oversight, Review, Evaluation, and Revision

51. Oversee and monitor Recovery Plan implementation.

511. Conduct section 7 consultation on any Federal actions that may affect Mexican spotted owls.

5111. Conduct a workshop between Recovery Team and FWS consultation biologists on evaluation of projects for Recovery Plan compliance.

5112. Consult programmatically on each agency's incorporation of the Recovery Plan into land management policy and guidance documents.

5113. Review projects for compliance with the Recovery Plan.

512. Form Recovery Unit Working Teams for each Recovery Unit.

5121. Appoint working Team members

5122. Develop charter, protocols for agreeing upon recommendations to be made to Recovery Team (e.g., voting protocols).

5123. Conduct training session with Recovery Team to ensure understanding and consistent interpretation of the Recovery Plan.

5124. Conduct Recovery Plan implementation workshops with biologists and other land-management personnel.

5125. Convene approximately quarterly or as needed.

5126. Working Team Leaders attend all Recovery Team meetings.

513. Retain Recovery Team throughout the life of the Recovery Plan.

5131. Convene Recovery Team semi–annually for a minimum of two years after Recovery Plan adoption.

5132. Convene Recovery Team annually thereafter.

52. Oversee Research

521. Recovery Unit Working Teams should review and prioritize research proposals and make recommendations to the Recovery Team.

522. Recovery Unit Working Teams should annually update the FWS and the Recovery Team on planned studies.

53. Review, evaluate, and revise recovery plan as appropriate.

    531. Recovery Unit Working Teams should review plan implementation at least annually, reporting the results to the FWS and the Recovery Team.
    532. Recovery Unit Working Teams should review research and suggest plan revisions, if any, to the FWS and Recovery Team.

54. Recovery Unit Working Teams should provide technical assistance when requested.

    541. Provide land managers with technical assistance in designing projects to minimize impacts on spotted owls.
    542. Provide technical assistance in procuring funding and logistic support for research projects.
    543. Provide technical assistance in developing spotted owl management plans.
    544. Provide technical assistance in developing conservation agreements.
    545. Provide other technical assistance as needed.

55. Conduct Mexican spotted owl status reviews.

56. State and private lands.

    561. Conduct assessment of Mexican spotted owl status on State and private lands.
    562. Promulgate rule under 4(d) of the Endangered Species Act to provide for Mexican spotted owl conservation on State and private lands.

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D. IMPLEMENTATION AND COST SCHEDULE

Table IV.D.1 displays estimated costs and an approximate schedule for implementing the recovery tasks listed in the stepdown outline provided in IV.C. More detailed information on the recommended actions is provided in Part III. The following material explains relevant details about Table IV.D.1:

Task: This column lists specific tasks recommended in Part III. The format of this column is similar to that used in the stepdown outline in III.C., with each task under one of five general task categories (preceded by an Arabic numeral). In some cases "subtasks" are included if the Recovery Team wished to identify specific intermediate actions to accomplish an ultimate objective. Please refer to the stepdown outline in III.C for a more detailed description of each task. Part III provides yet more detail, such as suggested methodologies and rationales.

Task No.: This column lists the task numbers as developed in the stepdown outline (IV.C).

P: This column assigns priority numbers as follows:

> **1:** Tasks that must be completed to achieve the delisting criteria detailed in III.A. (Example: Population monitoring); tasks required by law (Example: Section 7 consultation), and other tasks essential to Recovery Plan implementation (Example: amendment of agency planning documents).
>
> **2:** Tasks that should be done to help attain the recovery objective. (Example: Restoration of degraded riparian areas).
>
> **3:** Tasks that should be done to implement the Recovery Plan efficiently or to otherwise enhance spotted owl management. (Example: general spotted owl inventory).

Dur.: The approximate duration (in years) of each task. Items that are expected to take less than one year are assigned the number "1." Tasks that are ongoing are labeled "cont." (continuous). Some tasks can be done to varying degrees or intensities, particularly research projects. In those cases, the duration is labeled "tbd" (to be determined).

Resp. Party: Assigns lead responsibility of each task to a specific party. This does not necessarily mean that the indicated entity has sole responsibility for completion of a specific task; the Recovery Team recommends that agencies, Tribes, and others work cooperatively on recovery tasks whenever possible.

The following abbreviations are used:

AA = As appropriate
Ac = Action agency[1]
All = All involved[2]
AZ = State of Arizona
BLM = Bureau of Land Management
CO = State of Colorado
DOD = Department of Defense
FS = Forest Service
FWS= Fish and Wildlife Service
MA = Mescalero Apache
MEX = Mexico
NAV = Navajo
NM = State of New Mexico
NPS = National Park Service
PI = Principle Investigator
RT = Recovery Team
SCA = San Carlos Apache
tbd = to be determined
UT = State of Utah
WMA = White Mtn. Apache
WT = Working Team[3]

[1] Used in situations such as under "Other Federal agencies."

[2] All parties involved in a cooperative effort such as the population monitoring program.

[3] Used both for all Recovery Unit Working Teams collectively or for the appropriate WT for a Recovery Unit.

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Cost Estimates: The figures in this column represent the estimated costs (x$1,000) of carrying out the recommended tasks in each fiscal year (FY) indicated. Estimated costs are rounded to the nearest $1,000, i.e., a project estimated at $200 will show "0"; a project estimated at $500 will show "1", etc. Some of the tasks assigned "NA" will be so labeled because no additional cost attributable to Mexican spotted owl recovery will be incurred. These include activities that are either already part of land management programs or those that can be paid for through commercial receipts (e.g. forest health enhancement/protection projects). No cost estimates are given on tasks for Mexico because the Recovery Team was unable to obtain the information.

Obviously, it is impossible to accurately predict the costs of many tasks. For example, the cost to carry out recommended research activities can vary widely depending on the study design, the duration of the study, and other factors. Similarly, the fiscal year(s) under which the costs are placed may or may not be the fiscal year in which the cost is actually incurred; again, it is impossible predict when a project will be undertaken. Finally, in cases such as pre-project inventories, costs can only be estimated on a per unit basis (e.g., $1.25/acre).

Table IV.D.1 Implementation and Cost Schedule

Task	Task No.	P	Dur. (Yrs)	Resp. Party	Cost Estimates (x $1,000)									
					FY96	FY97	FY98	FY99	FY00	FY01	FY02	FY03	FY04	FY05
1. Resource Management Programs														
Land Management Policy Amendment														
Federal Agencies	1111	1	2	FS	5	0	0	0	0	0	0	0	0	0
	1112	2	2	BLM	25	25	0	0	0	0	0	0	0	0
	1113	2	2	NPS	25	25	0	0	0	0	0	0	0	0
	1114	2	2	DOD	25	25	0	0	0	0	0	0	0	0
Tribes	1121	2	1	WMA	25	0	0	0	0	0	0	0	0	0
	1122	2	1	MA	25	0	0	0	0	0	0	0	0	0
	1123	2	1	SCA	25	0	0	0	0	0	0	0	0	0
	1124	2	1	NAV	25	0	0	0	0	0	0	0	0	0
	1125	3	1	AA	tbd	tbd	0	0	0	0	0	0	0	0
States	1131	3	1	AZ	tbd	tbd	0	0	0	0	0	0	0	0
	1132	3	1	NM	tbd	tbd	0	0	0	0	0	0	0	0
	1133	3	1	UT	tbd	tbd	0	0	0	0	0	0	0	0
	1134	3	1	CO	tbd	tbd	0	0	0	0	0	0	0	0
Mexico	1141	1	1	FWS	5	0	0	0	0	0	0	0	0	0
	1142	1	1	MEX										
Pre-Project Inventories														
Federal Agencies	1211	1	cont.	FS	$1.25/acre	→	→	→	→	→	→	→	→	→
	1212	1	cont.	BLM	"	→	→	→	→	→	→	→	→	→
	1213	1	cont.	NPS	"	→	→	→	→	→	→	→	→	→
	1214	1	cont.	DOD	"	→	→	→	→	→	→	→	→	→
Tribes	1221	1	cont.	WMA	"	→	→	→	→	→	→	→	→	→
	1222	1	cont.	MA	"	→	→	→	→	→	→	→	→	→
	1223	1	cont.	SCA	"	→	→	→	→	→	→	→	→	→
	1224	1	cont.	NAV	"	→	→	→	→	→	→	→	→	→
	1225	1	cont.	AA	"	→	→	→	→	→	→	→	→	→
States	1231	1	cont.	AZ	"	→	→	→	→	→	→	→	→	→
	1232	1	cont.	NM	"	→	→	→	→	→	→	→	→	→
	1233	1	cont.	UT	"	→	→	→	→	→	→	→	→	→
	1234	1	cont.	CO	"	→	→	→	→	→	→	→	→	→
Mexico	124	1	cont.	MEX										

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Table IV.D.1. continued

					Cost Estimates (x $1,000)									
Task	Task No	P	Dur. (Yrs)	Resp. Party	FY96	FY97	FY98	FY99	FY00	FY01	FY02	FY03	FY04	FY05
2. Active Management														
Forest Health														
Federal Agencies	2111	1	cont.	FS	0	0	0	0	0	0	0	0	0	0
	2112	3	cont.	BLM	0	0	0	0	0	0	0	0	0	0
	2113	3	cont.	NPS	0	0	0	0	0	0	0	0	0	0
	2114	2	cont.	DOD	0	0	0	0	0	0	0	0	0	0
	2115	3	cont.	AA	0	0	0	0	0	0	0	0	0	0
Tribes	2121	2	cont.	WMA	0	0	0	0	0	0	0	0	0	0
	2122	2	cont.	MA	0	0	0	0	0	0	0	0	0	0
	2123	2	cont.	SCA	0	0	0	0	0	0	0	0	0	0
	2124	2	cont.	NAV	0	0	0	0	0	0	0	0	0	0
	2125	3	cont.	AA	0	0	0	0	0	0	0	0	0	0
States	2131	3	cont.	AZ	0	0	0	0	0	0	0	0	0	0
	2132	3	cont.	NM	0	0	0	0	0	0	0	0	0	0
	2133	3	cont.	UT	0	0	0	0	0	0	0	0	0	0
	2134	3	cont.	CO	0	0	0	0	0	0	0	0	0	0
Mexico	214	1	cont.	MEX										
Riparian Management														
Lowland Areas	2211	2	cont.	BLM	0	0	0	0	0	0	0	0	0	0
	2212	2	cont.	AZ	tbd	→	→	→	→	→	→	→	→	→
	2213	2	cont.	NM	"	→	→	→	→	→	→	→	→	→
	2214	2	cont.	UT	"	→	→	→	→	→	→	→	→	→
	2215	2	cont.	CO	"	→	→	→	→	→	→	→	→	→
	2216	2	cont.	MEX										
Mid- and Upland Areas														
Federal Lands	22211	1	cont.	FS	0	0	0	0	0	0	0	0	0	0
	22212	3	cont.	BLM	0	0	0	0	0	0	0	0	0	0
	22213	3	cont.	NPS	0	0	0	0	0	0	0	0	0	0
	22214	3	cont.	DOD	0	0	0	0	0	0	0	0	0	0
	22215	3	cont.	AA	0	0	0	0	0	0	0	0	0	0

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Table IV.D.1. continued

Task	Task No.	P	Dur. (Yrs)	Resp. Party	FY96	FY97	FY98	FY99	FY00	FY01	FY02	FY03	FY04	FY05
					Cost Estimates (x $1,000)									
Mid- and Upland Areas (continued)														
Tribes	22221	2	cont.	WMA	0	0	0	0	0	0	0	0	0	0
	22222	2	cont.	MA	0	0	0	0	0	0	0	0	0	0
	22223	2	cont.	SCA	0	0	0	0	0	0	0	0	0	0
	22224	2	cont.	NAV	0	0	0	0	0	0	0	0	0	0
	22225	3	cont.	AA	0	0	0	0	0	0	0	0	0	0
Mexico	2223	1	cont.	MEX										
Long-term Management Plan														
Appoint Team	231	1	1	FWS	0	0	0	0	0	0	1	0	0	0
Develop Draft Plan	232	2	2	FWS	0	0	0	0	0	0	100	100	0	0
Peer, Public Review	233	1	1	FWS	0	0	0	0	0	0	0	5	5	0
Produce Final Plan	234	1	1	FWS	0	0	0	0	0	0	0	0	50	50
Develop Implementation Documents														
Joint Federal EIS	2351	1	2	FS	0	0	0	0	0	0	0	0	0	tbd
Tribal Documents	2352	1	1	WMA	0	0	0	0	0	0	0	0	0	tbd
	2353	1	1	MA	0	0	0	0	0	0	0	0	0	tbd
	2354	1	1	SCA	0	0	0	0	0	0	0	0	0	tbd
	2355	1	1	NAV	0	0	0	0	0	0	0	0	0	tbd
	2356	2	1	AA	0	0	0	0	0	0	0	0	0	tbd
State MOUs	23571	2	1	AZ	0	0	0	0	0	0	0	0	0	tbd
	23572	2	1	NM	0	0	0	0	0	0	0	0	0	tbd
	23573	2	1	UT	0	0	0	0	0	0	0	0	0	tbd
	23574	2	1	CO	0	0	0	0	0	0	0	0	0	tbd
Mexico	2358	1	2	MEX										
3. Monitoring														
Population														
Secure Funding	311	1	cont.	All	5	5	5	5	5	5	5	5	5	5
Select PI	312	1	1	All	2	0	0	0	0	0	0	0	0	0
Dev. Methodology	313	1	1	PI	25	0	0	0	0	0	0	0	0	0
Review Methodology	314	1	1	RT	10	0	0	0	0	0	0	0	0	0
Conduct Pilot Study	315	1	1	PI	500	0	0	0	0	0	0	0	0	0
Evaluate/Revise Methodology	316	1	1	PI	25	10	0	0	0	0	0	0	0	0
Implement Monitoring	317	1	10	PI	0	1500	1500	1500	1500	1500	1500	1500	1500	1500

Table IV.D.1. continued

Task	Task No.	P	Dur. (Yrs)	Resp. Party	Cost Estimates (x $1,000)									
					FY96	FY97	FY98	FY99	FY00	FY01	FY02	FY03	FY04	FY05
3. Monitoring (continued)														
Macrohabitat														
Acquire Imagery	3211	1	1	AA	70	0	0	0	0	0	0	0	0	0
Process Imagery	3212	1	1	AA	50	0	0	0	0	0	0	0	0	0
Acquire Imagery	3213	1	1	AA	0	0	0	0	70	0	0	0	0	0
Process Imagery	3214	1	1	AA	0	0	0	0	50	0	0	0	0	0
Analyze Change	3215	1	1	AA	0	0	0	0	0	50	0	0	0	0
Acquire Imagery	3216	1	1	AA	0	0	0	0	0	0	0	0	0	70
Process Imagery	3217	1	1	AA	0	0	0	0	0	0	0	0	0	50
Analyze Change	3218	1	1	AA	0	0	0	0	0	0	0	0	0	50
Microhabitat														
Measure Habitat Variables	3221	1	1	AA	200	200	200	200	200	200	200	200	200	200
Design Treatment	3222	1	1	AA	0	0	0	0	0	0	0	0	0	0
Conduct Treatment	3223	1	1	AA	0	0	0	0	0	0	0	0	0	0
Measure Habitat Variables	3224	1	1	AA	0	200	200	200	200	200	200	200	200	200
Analyze Effects	3225	1	1	AA	0	50	50	50	50	50	50	50	50	50
Measure Habitat Variables	3226	1	1	AA	0	0	0	0	0	0	0	0	0	200
Analyze Habitat Trajectory	3227	1	1	AA	0	0	0	0	0	0	0	0	0	50
4. Research														
Dispersal Studies														
Connectivity	4111	2	tbd	PI	80	80	80	80	0	0	0	0	0	0
Dispersal Habitat	4112	2	tbd	PI	40	40	40	40	0	0	0	0	0	0
Genetic Studies														
Genetic Isolation	4121	3	tbd	PI	50	50	50	0	0	0	0	0	0	0
Gene Flow	4122	3	tbd	PI	50	50	50	0	0	0	0	0	0	0
Habitat Studies														
Habitat Selection	4131	2	tbd	PI	120	120	120	120	0	0	0	0	0	0
Habitat/Fitness	4132	2	tbd	PI	150	150	150	150	175	175	175	200	200	200
Land Use Habitat Influence														
Silviculture	4141	1	tbd	PI	200	200	200	200	200	300	300	300	300	300
Grazing	4142	1	tbd	PI	100	100	100	100	100	150	150	150	150	150
Prescribed Fire	4143	2	tbd	PI	75	75	75	75	75	120	120	120	120	100
Recreation	4144	2	tbd	PI	30	30	30	30	30	0	0	0	0	0

Table IV.D.1. continued

Task	Task No.	P	Dur. (Yrs)	Resp. Party	Cost Estimates (x $1,000) FY96	FY97	FY98	FY99	FY00	FY01	FY02	FY03	FY04	FY05
4. Research (continued)														
Disturbance														
Noise/Visual	4151	2	tbd	PI	80	80	80	0	0	0	0	0	0	0
Encroachment	4152	2	tbd	PI	80	80	80	0	0	0	0	0	0	0
Recovery Plan Implementation														
Vertebrates	4161	3	tbd	PI	300	300	300	400	400	400	400	450	450	450
Invertebrates	4162	3	tbd	PI	100	100	100	130	130	130	130	150	150	150
Plants/Communities	4163	3	tbd	PI	100	100	100	130	130	130	130	150	150	150
Abiotic Features	4164	3	tbd	PI	100	100	100	130	130	130	130	150	150	150
Ecosystem Function	4165	3	tbd	PI	200	200	200	200	250	250	250	300	300	300
General Inventory														
Federal Lands	4211	2	cont.	FS	$1.25/acre	→	→	→	→	→	→	→	→	→
	4212	2	cont.	BLM	"	→	→	→	→	→	→	→	→	→
	4213	2	cont.	NPS	"	→	→	→	→	→	→	→	→	→
	4214	2	cont.	DOD	"	→	→	→	→	→	→	→	→	→
	4215	3	cont.	AA	"	→	→	→	→	→	→	→	→	→
Tribal Lands	4221	2	cont.	WMA	"	→	→	→	→	→	→	→	→	→
	4222	2	cont.	MA	"	→	→	→	→	→	→	→	→	→
	4223	2	cont.	SCA	"	→	→	→	→	→	→	→	→	→
	4224	2	cont.	NAV	"	→	→	→	→	→	→	→	→	→
	4225	3	cont.	AA	"	→	→	→	→	→	→	→	→	→
State and Private Lands	4231	3	cont.	AZ	"	→	→	→	→	→	→	→	→	→
	4232	3	cont.	NM	"	→	→	→	→	→	→	→	→	→
	4233	3	cont.	UT	"	→	→	→	→	→	→	→	→	→
	4234	3	cont.	CO		→	→	→	→	→	→	→	→	→
	424	2	cont.	MEX										
Central Information Facility														
Geographic Information System														
Update Owl Locations	4311	3	cont.	AA	1	1	1	1	1	1	1	1	1	1
Update Habitat Coverage	4312	3	cont.	AA	0	2	0	0	0	2	0	0	0	2
Maintain Bibliography	432	3	cont.	tbd	1	1	1	1	1	1	1	1	1	1
Distribute Information	433	3	cont.	tbd	1	1	1	1	1	1	1	1	1	1

Table IV.D.1 (continued)

Task	Task No.	P.	Dur. (Yrs)	Resp. Party	FY96	FY97	FY98	FY99	FY00	FY01	FY02	FY03	FY04	FY05
					Cost Estimates (x $1,000)									
5. Oversight, Review, Evaluation and Revision														
Oversee/Monitor Implementation														
Section 7 Consultation														
Workshop	5111	2	1	FWS, RT	3	0	0	0	0	0	0	0	0	0
Programmatic Consultation	5112	1	1	FWS, Ac	10	[illegible]	0	0	0	0	0	0	0	0
Project Consultations	5113	1	ong.	FWS, A	40	40	40	40	40	40	40	40	40	40
Working Teams														
Appoint Teams	5121	1	1	FWS	3	0	0	0	0	0	0	0	0	0
Develop Charter, Rules	5122	1	1	RT, WT	1	0	0	0	0	0	0	0	0	0
Training Sessions	5123	2	1	RT, WT	5	0	0	0	0	0	0	0	0	0
Workshops	5124	1	1	WT	10	0	0	0	0	0	0	0	0	0
Review Implementation	5125	1	ong.	WT	2	2	2	2	2	2	2	2	1	1
Attend RT Meetings	5126	1	ong.	WT	4	4	2	2	2	2	2	2	1	1
Recovery Team														
Semiannual Meetings	5131	2	2	RT	8	8	0	0	0	0	0	0	0	0
Annual Meetings	5132	2	ong.	RT	0	0	4	4	4	4	4	4	4	4
Oversee Research														
Review Progress	521	1	ong.	WT	2	2	2	2	2	2	2	2	2	2
Update FWS, RT	522	1	ong.	WT	1	1	1	1	1	1	1	1	1	1
Review, Evaluate, Revise Recovery Plan														
Report RP Progress to FWS, RT	531	2	ong.	WT	1	1	1	1	1	1	1	1	1	1
Suggest RP Revisions	532	2	ong.	WT	1	1	1	1	1	1	1	1	1	1
Provide Technical Assistance														
Aid in Project Design	541	2	ong.	WT	2	2	2	2	2	2	2	2	2	2
Procure Research Lands, Sup	542	2	ong.	WT	1	1	1	1	1	1	1	1	1	1
Help Develop Mgmt. Plans	543	2	ong.	WT	2	2	2	0	0	0	0	0	0	0
Help Develop Cons. Agreements	544	2	ong.	WT	2	2	2	0	0	0	0	0	0	0
Other Technical Assistance	545	2	ong.	WT	1	1	1	1	1	1	1	1	1	1
Status Reviews	55	1	1	FWS	0	0	0	0	10	0	0	0	0	10
State/Private Lands														
Assess Situation	561	2	1	FWS	5	0	0	0	0	0	0	0	0	0
Promulgate 4(d) Rule	562	2	1	FWS	0	15	0	0	0	0	0	0	0	0

GLOSSARY

Acronyms and Abbreviations

Act - Endangered Species Act of 1973, as amended
AIC - Akaike's Information Criteria
AK - Adaptive kernel
AOU - American Ornithologists' Union
ANOVA - Analysis of variance: a statistical evaluation procedure
AZ - Arizona
BLM - Bureau of Land Management
CJS - Cormack-Jolly-Seber: a population model
CO - Colorado
CSA - Coconino Study Area: a demographic study area
DOD - Department of Defense
EA - Environmental Assessment
EIS - Environmental Impact Statement
FEMAT - Forest Ecosystem Management Assessment Team
FS - Forest Service (USDA Forest Service)
FWS - Fish and Wildlife Service (U.S. Fish and Wildlife Service; USDI Fish and Wildlife Service)
FY - Federal budget fiscal year: 1 October to 30 September
GIS - Geographic Information System
GSA - Gila Study Area: a demographic study area
HCA - Habitat Conservation Area
ISC - Interagency Scientific Committee
LMP - Land Management Plan
LRT - Likelihood ratio tests
LSR - Late Successional Reserve
MANOVA - Multivariate analysis of variance
MCP - Minimum convex polygon
MBTA - Migratory Bird Treaty Act
NBS - National Biological Service
NEPA - National Environmental Policy Act
NFMA - National Forest Management Act
NM - New Mexico
NPS - National Park Service (USDI National Park Service)
PAC - Protected Activity Center
RU - Recovery Unit
SISA - Sky Island Study Area
SOHA - Spotted Owl Habitat Area
SOMA - Spotted Owl Management Area
TES - Terrestrial Ecosystem Survey
USDA - United States Department of Agriculture
USDI - United States Department of Interior
USGS - United States Geological Survey
UT - Utah

Terms

Adaptive kernel (AK) - refers to a method of estimating home-range size. This method involves estimating a bivariate probability distribution from the observed animal locations, and can be used to compute the area containing a specified proportion of those locations.

Adaptive management - refers to a p[illegible]cess in which policy decisi[illegible] [illegible]lemented within a fram[illegible] [illegible] driven experiments to tes[illegible] and assumptions inherent in ma[illegible] ment plans.

Algorithm - a mathematical formula for solving a problem.

Basal area - the cross-sectional area of a tree stem near its base. Generally measured at breast height (including bark).

Biomass - with respect to individuals, this refers to the weight (mass) of a plant or an animal. With respect to areas or communities, refers to the total mass of living organisms in that area or community at any given time. With respect to owl diet, used to refer to the relative contribution of one species (or group) of prey animals to the overall diet.

Birth-pulse population - a population assumed to have a discrete point in time during which all offspring are produced.

Bonferroni confidence interval - a family of simultaneous confidence intervals in which the width of each interval is adjusted downward to account for the estimation of simultaneous intervals. Basically, allows for multiple comparisons without inflating the Type I error rate.

Bosque - a discrete grove or thicket of trees, particularly in lowland or riparian areas of the Southwestern United States and Mexico; for example, a cottonwood bosque or a mesquite bosque.

Canopy - a layer of foliage, generally the uppermost layer, in a forest stand. Can be used to refer to mid- or understory vegetation in multi-layered stands.

Canopy closure - an estimate of the amount of overhead tree cover (also canopy cover).

Clearcut - an area where the entire stand of trees has been removed in one cutting.

Climax species - any species that is characteristic of a plant community that through natural processes reaches the apex of its development after sufficient time. The opposite of seral species.

Closed population - a population that receives no immigrants from other populations, and from which no individuals emigrate to other populations.

Cohort - individuals of the same age, resulting from the same birth-pulse.

Commercial forest land - forested land deemed tentatively suitable for the production of crops of timber, that has not been withdrawn administratively from timber production (see reserved land).

Confidence interval - an interval constructed around a parameter estimate, in which that estimate should occur with a specified probability, such as 95% of the time.

Connectivity - an estimate of the extent to which intervening habitats connect subpopulations of spotted owls.

Cordillera - a mountain range or chain.

Cordilleran - of or relating to a range of mountains.

Dbh - diameter at breast height, a standard measure of tree size.

Demography - the quantitative analysis of population structure and trend.

Demographic stochasticity - fluctuations in population size driven by random fluctuations in birth and death rates.

Dispersal - The movement of organisms from their birth place to another location where they produce offspring.

Disturbance - significant alteration of habitat structure or composition. May be natural (e.g., fire) or human-caused events (e.g., timber harvest).

Early seral stage - an area that is in the early stages of ecological succession.

Ecological succession - the orderly progression of an area through time from one vegetative community to another in the absence of disturbance. For example, an area may proceed from grass-forb through aspen forest to mixed-conifer forest.

Ecosystem - an interacting biophysical system of organisms and their environment.

Emigration - permanent movement of individuals away from a population.

Encinal - of or relating to oaks, particularly plant communities dominated by live oaks.

Environmental stochasticity - random variation in environmental attributes, such as weather patterns or fire regimes.

Even-aged forest - used to refer to forests composed of trees with a time span of ≤20 yrs between oldest and youngest individuals.

Even-aged management - the application of a combination of actions that result in the creation of stands in which trees are essentially all of the same age. Cutting methods that produce even-aged stands include clearcuts, seed-tree cuts, and shelterwood cuts.

Fecundity - a statistical parameter of productivity determined by the number of same-gender offspring produced by each adult in a population. Thus, either male offspring produced per male adult or female offspring produced per female adult is a measure of fecundity.

Fire regime - a description of the frequency, severity, and extent of fires that typically occur in an area or vegetation type.

Floater - a member of a spotted owl population that does not hold, maintain, or defend a territory (see Franklin 1992).

Forb - a broadleaved, herbaceous plant; for example, columbine.

Fragmentation - the process of reducing the size and connectivity of habitat patches.

Fuel ladder - dead or living fuels that connect fuels on the forest floor to the canopy, and promote the spread of surface fires to tree crowns.

Fuel loads - the amount of combustible material present per unit area.

Fuels - combustible materials.

Fuelwood - wood, either green or dead, harvested for purposes of cooking or space heating, and usually measured in cords. (1 cord = 128 cubic feet.)

Geographical Information System (GIS) - a computer system capable of storing and manipulating spatial data.

Gene flow - the movement of genetic material among populations.

Genetic stochasticity - random changes in gene frequencies within a population; may result from factors such as inbreeding and mutation.

Graminoids - any plants of the grass family in particular and also those plants in other families that have a grass-like form or appearance (for example, sedges).

Group-selection cutting - removal during harvest of groups of trees.

Habitat - suite of existing environmental conditions required by an organism for survival and reproduction. The place where an organism typically lives.

Habitat fragmentation - see fragmentation.

Habitat mosaic - the mixture of habitat conditions across a landscape.

Habitat type - see vegetation type.

Hanging canyon - a side canyon, the mouth of which lies above the floor of a larger canyon to which it is tributary.

Home range - the area used by an animal in its day-to-day activities.

Immigration - the movement of individuals from other areas into a given area.

Intermountain Region - an administrative region of the USDA Forest Service, lying between the Pacific Coastal and Rocky Mountain Ranges and including Utah, Nevada, southern Idaho, and parts of Wyoming and Montana.

Lambda - the finite rate of change in population size. If lambda is greater than 1, the population trend is increasing; if lambda equals 1, the population trend is stable; if lambda is less than 1, the population trend is decreasing.

Land Management Plan (LMP) - a plan written for the management of a National Forest. These plans were mandated by the National Forest Management Act of 1976.

Late seral stage forest - a forest in the latter stages of development, usually dominated by large, old trees.

Leslie matrix - a two-dimensional array of numbers representing age- or stage-specific estimates of birth and death rates, used to project population age (or stage) structure through time.

Life table - mathematical table of age- or stage-specific birth and death rates of a population.

Macrohabitat - landscape-scale features that are correlated with the distribution of a species; often used to describe seral stages or discrete arrays of specific vegetation types.

Madrean - pertaining to Mexico's Sierra Madre cordillera, or to plant species or communities whose primary affinity is to that region (see also Petran).

Madrean pine-oak forest - forests in which any of several pines characterize the overstory, and midstory oaks are mostly evergreen species. Many of the dominant species are Madrean in affinity. See Marshall (1957) for descriptions. This habitat was included as Pine-oak by Fletcher and Hollis (1994).

Mesic - of or relating to conditions between hydric and xeric or the specific quality of being adapted to conditions between wet and dry.

Metapopulation - systems of local populations connected by dispersing individuals.

Microhabitat - habitat features at a fine scale; often identifies a unique set of local habitat features.

Microtine - any vole of the genus *Microtus*.

Migration - the seasonal movement from one area to another and back.

Minimum convex polygon (MCP) - a method used to estimate home-range size. This

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method involves forming a polygon by connecting the outermost animal locations with a series of convex lines, then computing the area of that polygon.

Mixed-conifer forest type - overstory species in these forests include Rocky Mountain Douglas-fir, white fir, Rocky Mountain ponderosa pine, quaking aspen, southwestern white pine, limber pine, and blue spruce. Refer to II.C for a more precise discussion and definition of mixed-conifer forest type.

Model - a representation of reality, based on a set of assumptions, that is developed and used to describe, analyze, and understand the behavior of a system of interest.

Monitoring - the process of collecting information to track changes of selected parameters over time.

Mousing - a technique used to assess reproductive status of a pair of spotted owls. Entails feeding mice to adult owls and observing the owls' subsequent behavior.

Multi-layered (or multi-storied) stands - forest stands with ≥2 distinct canopy layers. Applied to forest stands that contain trees of various heights and diameters, and therefore support foliage at various heights in the vertical profile of the stand.

Null hypothesis - a hypothesis stating that there is no difference between units being compared.

Other forest and woodland types - vegetation types that are neither "restricted" or within PACs (see definitions of those terms) as to management recommendations provided in this Recovery Plan.

Old growth - an old forest stand, typically dominated by large, old trees, with relatively high canopy closure and a high incidence of snags, as well as logs and other woody debris.

Overstory - the highest limbs and foliage of a tree, and consequently extending and relating to the upper layers of a forest canopy.

Pellet - a compact mass of undigested material remaining after preliminary digestion and eliminated by regurgitation rather than by defecation.

Peromyscid - any mouse in the genus *Peromyscus* of the family Muridae (formerly Cricetidae).

Petran - pertaining to the Rocky Mountain area. Used to identify plant associations or species that have their primary affinity to the Rocky Mountain area (see also Madrean).

Physiographic province - a geographic region in which climate and geology have given rise to a distinct array of land forms and habitats.

Pine-oak forest type - stands within the *Pinus ponderosa* and *Pinus leiophylla* series that exhibit a pine overstory and oak understory. Refer to II.C for these criteria and a more precise discussion and definition of pine-oak forest type.

Precommercial thinning - the practice of removing some of the smaller trees in a stand so that remaining trees will grow faster.

Prescribed fire - a fire burning under specified conditions, may result from either planned or unplanned ignitions.

Ponderosa pine forest type - any forested stand of the *Pinus ponderosa* Series not included in the pine-oak forest type definition, or any stand that qualifies as pure (i.e., any stand where a single species contributes ≥80 % of the basal area of dominant and codominant trees) ponderosa pine, regardless of the series or habitat (see also Eyre 1980). Refer to Part II.C for a more precise discussion and definition of ponderosa pine forest type.

Population - a collection of individuals that share a common gene pool.

Population density - the number of individuals per unit area.

Population persistence - the capacity of a population to maintain sufficient numbers and distribution over time.

Population viability - the probability that a population will persist for a specific period of time, despite demographic and environmental stochasticity.

Power - with respect to statistical comparisons, refers to the probability of not making a

Type-II error.

Protected Activity Center (PAC) - an area established around an owl nest (or sometimes roost) site, for the purpose of protecting that area. Management of these areas is largely restricted to managing for forest health objectives.

Protected areas - as used in this Plan, refers to areas that are protected, and where most management activities are very restricted or disallowed. Includes Protected Activity Centers.

Recovery - as provided by the Endangered Species Act and its implementing regulations, the process of returning a threatened or endangered species to the point at which protection under the Endangered Species Act is no longer necessary.

Recovery Plan - as provided by the Endangered Species Act, a plan for management of a threatened or endangered species that lays out the steps necessary to recover a species (see "Recovery").

Recovery Team - a team of experts appointed by the Fish and Wildlife Service whose charge is development of a Recovery Plan (see "Recovery Plan").

Recovery Unit (RU) - a specific geographic area, identified mainly from physiographic provinces, used to evaluate the status of the Mexican spotted owl.

Recruitment - the addition of individuals to a population from birth and immigration.

Reserved lands - lands that have been administratively withdrawn from commercial activities, such as wilderness areas or research natural areas.

Restricted Areas - as used in this Plan, refers to areas that are not protected (see Protected Areas), but where specific guidelines for management activities are proposed.

Riparian - of or relating to a river; specifically applied to ecology, "riparian" describes the land immediately adjoining and directly influenced by streams. For example, riparian vegetation includes any and all plant-life growing on the land adjoining a stream and directly influenced by that stream.

Riparian forests - forests along rivers, streams, and other wetland environments, typically characterized by the presence of riparian-obligate plants such as cottonwoods, willows, sycamores, or alders. Descriptions are provided by Dick-Peddie (1993) and others.

Rocky Mountain Region - An administrative region of the USDA Forest Service, including Colorado, Nebraska, South Dakota, and parts of Wyoming.

Rotation - the planned number of years between regeneration of a forest stand and final harvest of that stand.

Salvage - see sanitation salvage.

Sanitation salvage - removal of dead, damaged, or susceptible trees primarily to prevent the spread of pests or pathogens and to promote forest health.

Seed-tree cut - an even-aged regeneration cutting in which only a few seed trees are retained per hectare. Shelterwood cuts retain more seed trees.

Seral species - any plant or animal that is typical of a seral community (stage).

Seral stage - Any plant community whose plant composition is changing in a predictable way; for example, an aspen community changing to a coniferous forest community.

Shelterwood cut - an even-aged regeneration cutting in which new tree seedlings are established under the partial shade of remnant seed trees.

Silviculture - the practice of controlling the establishment, composition, and growth of forests.

Single-tree selection cutting - a cutting method based on removal of individual trees, rather than groups of trees (see also group selection cutting).

Sink - in a population sense, refers to a population whose death rate exceeds its birth rate. Such a population is maintained by immigration from other populations (see source), and is not expected to contribute to long-term population maintenance.

Slash - the residue left on the ground after logging, including logs, uprooted stumps, branches, twigs, leaves, and bark.

Southwestern Region - an administrative unit of the USDA Forest Service, including Arizona and New Mexico; and an administrative unit of the USDI Fish and Wildlife Service , including Arizona, New Mexico, Texas and Oklahoma.

Snag - a standing dead tree.

Source - in a population sense, refers to a population where birth rate exceeds death rate. Such a population produces an excess of juveniles that can disperse to other populations (see sink)

Spruce-fir forest type - high-elevation forests occurring on cold sites with short growing seasons, heavy snow accumulations, and strong ecological and floristic affinities to cold forests of higher latitudes. In general, dominant trees include Englemann spruce, subalpine and/or corkbark fir, or sometimes bristlecone pine. Refer to Part II.C for a more precise discussion and definition of spruce-fir forest type.

Stand - any homogeneous area of vegetation with more or less uniform soils, landform, and vegetation. Typically used to refer to forested areas.

Stochastic - random or uncertain.

Stringers - narrow bands of trees that extend into confined areas of suitable habitat such as in ravines.

Subpopulation - a well-defined set of individuals that comprises a subset of a larger, interbreeding population (see also metapopulation).

Survivorship - the proportion of newborn individuals that are alive at any given age.

Team - the Mexican Spotted Owl Recovery Team

Technical Team - the Utah Technical Team; an interagency team charged with providing management suggestions for the Mexican spotted owl.

Terrestrial Ecosystem Survey (TES) - a system of ecosystem classification, inventory, mapping, and interpretation based upon terrestrial vegetation and environmental factors, used by the USDA Forest Service, Southwestern Region. Ecosystems are defined by combinations of potential vegetation, soils, and climates. Land is partitioned into mapping units based upon inventory data, classification, and air photo interpretation.

Territory - the area that an animal defends against intruders of its own species. Not synonymous with home range, as parts of the home range are typically shared with other individuals.

Toe clipping - a procedure by which small animals are captured alive and marked as individuals for later recapture recognition by clipping off portions of one or more toes in unique combinations.

Trap-night - a standardized measurement of trapping effort in wildlife studies; equals one trap set for night. For example, one trap set for 10 nights and 10 traps set for one night both equal 10 trap-nights.

Turnover - in a population sense, refers to the rate at which individuals that die are replaced by other individuals.

Type-I error - the error made when a null hypothesis that is true is inappropriately rejected, as when concluding that two samples from a single population come from two different populations.

Type-II error - the error that is made when a null hypothesis that is false is not rejected, as when concluding that two samples from different populations came from a single population.

Understory - any vegetation whose canopy (foliage) is below, or closer to the ground than, canopies of other plants. The opposite of overstory.

Uneven-aged management - the application of a combination of actions needed to simultaneously maintain continuous tall forest cover, recurring regeneration of desirable species, and the orderly growth and development of trees through a range of diameter or age classes. Cutting methods that develop and maintain uneven-aged stands are single-tree selection and group selection.

Vegetation types - a land classification system based upon the concept of distinct plant associations. Vegetation or habitat types (plant associations) have been documented for western forests, and keys to their identification are available. The primary vegetation (or habitat) types used by Mexican spotted owls are discussed in II.C.

Viability - ability of a population to persist through time (see population viability).

Vital rates - collective term for age- or stage-specific demographic rates, such as birth and death rates, of a population.

Vole - any small rodent in the genus *Microtus*, *Clethrionomys*, or *Phenacomys*, all in the family Muridae.

Witches broom - a mass of profuse and densely packed twigs representing abnormal growth of a tree branch. Often results from infection by dwarf mistletoe.

Xeric - of or relating to perennially dry conditions or the specific quality of being adapted to dry conditions.

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APPENDIX A

THE RECOVERY TEAM AND ASSOCIATES

RECOVERY TEAM:

William M. Block, Team Leader; Wildlife Biologist.
Education: B.A., Economics, San Diego State University, 1974; B.S., Wildlife Biology, Michigan State University, 1981; M.S., Wildlife Biology, Humboldt State University, 1985; Ph.D., Wildland Resource Science, University of California, Berkeley, 1989.
Current Position: Project Leader, Research Wildlife Biologist, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Flagstaff, Arizona.

Fernando Clemente, Wildlife Biologist.
Education: B.S., Animal Science, University of Chapingo, Mexico, 1977; M.S., Wild Animal Nutrition, Colegio De Postgraduados, Mexico, 1984; Ph.D., Range and Wildlife Management, New Mexico State University, 1992.
Current Position: Head, Department of Wildlife Science, and Wildlife Professor, Colegio De Postgraduados, Campus San Luis Potosi, Mexico.

James L. Dick, Jr., Silviculturist.
Education: B.S., Forestry, University of Montana, 1967; M.S., Forest Resources, Pennsylvania State University, 1972.
Current Position: Forester, Recreation Staff Unit, USDA Forest Service, Southwestern Region, Albuquerque, New Mexico.

Alan B. Franklin, Spotted Owl Researcher.
Education: B.S., Wildlife Biology, Cornell University, 1979; M.S., Wildlife Biology, Humboldt State University, 1987; Doctoral Candidate, Department of Fisheries and Wildlife, Colorado State University.
Current Position: Project Leader, Humboldt State University Foundation, Humboldt State University, Arcata, California.

Joseph L. Ganey, Spotted Owl Researcher.
Education: B.S., Wildlife Biology, Humboldt State University, 1981; M.S., Biology, Northern Arizona University, 1988; Ph.D., Zoology, Northern Arizona University, 1991.
Current Position: Research Wildlife Biologist, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Flagstaff, Arizona.

W. H. Moir, Ecologist.
Education: Ph.D., Botany and Soils, Washington State University, 1965.
Current Position: Research Ecologist, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Sarah E. Rinkevich, Wildlife Biologist.
Education: B.S., Wildlife and Fisheries Science, University of Arizona, 1987; M.S., Wildlife Biology, Humboldt State University, 1991.
Current Position: Fish and Wildlife Biologist, USDI Fish and Wildlife Service, New Mexico Ecological Services State Office, Albuquerque, New Mexico.

Dean L. Urban, Landscape Ecologist.
Education: B.A., Botany and Zoology, Southern Illinois University, 1978; M.A., Zoology (Wildlife Ecology), Southern Illinois University, 1981; Ph.D., Ecology, University of Tennessee, 1986.
Current Position: Assistant Professor, School of Environment, Duke University.

James P. Ward, Jr., Spotted Owl Researcher.
Education: B.S., Wildlife Biology, Humboldt State University, 1985; M.S., Natural Resources (wildlife science emphasis), Humboldt State University, 1990; Doctoral Candidate, Department of Biology, Colorado State University.

Current Position: Wildlife Biologist, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado.

Gary C. White, Population Ecologist.
Education: B.S., Fisheries and Wildlife Biology, Iowa State University, 1970; M.S., Wildlife Biology, University of Maine-Orono, 1972; Ph.D., Zoology, Ohio State University, 1976; Post Doctorate, Wildlife Biology, Utah State University, 1976-77.
Current Position: Professor, Department of Fishery and Wildlife, Colorado State University, Fort Collins, Colorado.

RECOVERY TEAM-FISH AND WILDLIFE SERVICE LIAISON:

Steven L. Spangle, Fish and Wildlife Biologist — Regional Listing Coordinator, USDI Fish and Wildlife Service, Southwestern Regional Office, Albuquerque, New Mexico.

CONSULTANTS:

Pat Christgau, Coordinator, Mexican Spotted Owl Management, Arizona Game and Fish Department, Phoenix, Arizona.

Jack F. Cully, Jr., Assistant Unit Leader-Wildlife, National Biological Service, Kansas Cooperative Fish and Wildlife Research Unit, Kansas State University, Manhattan, Kansas.
Frank P. Howe, Utah Partners in Flight Coordinator, Utah Division of Wildlife Resources, Salt Lake City, Utah.

Tim Keitt, Graduate Research Assistant, Department of Biology, University of New Mexico, Albuquerque, New Mexico

Tom Spalding, Deputy Director, Arizona Department of Game and Fish, Phoenix, Arizona.

Steve Thompson, Biological Technician, Forest Resources Program, San Carlos Apache Tribe, San Carlos, Arizona.

Robert Vahle, Program Manager, Arizona Game and Fish Department, Region 1, Pinetop, Arizona.

MEETING FACILITATOR:

Kate W. Grandison, Intermountain Regional Spotted Owl Coordinator, Dixie National Forest, Cedar City, Utah.

ADMINISTRATIVE ASSISTANT:

Brenda Witsell, Biological Technician, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Flagstaff, Arizona.

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APPENDIX B

SCHEDULE OF TEAM MEETINGS

March 29 to April 4, 1993
    Albuquerque, New Mexico
April 27-30, 1993
    Flagstaff, Arizona
May 17-21, 1993
    Sierra Vista, Arizona
June 23-25, 1993
    Alamogordo, New Mexico
July 12-16, 1993
    Flagstaff, Arizona
August 16-19, 1993
    Pinetop, Arizona
September 14-16, 1993
    Fort Collins, Colorado
October 13-15, 1993
    Albuquerque, New Mexico
January 10-14, 1994
    Flagstaff, Arizona
February 22-25, 1994
    Fort Collins, Colorado
March 14-16, 1994
    Albuquerque, New Mexico
April 25-29, 1994
    Aguascalientes, Mexico
May 23-27, 1994
    Cedar City, Utah
June 27 to July 1, 1994
    Flagstaff, Arizona
August 8-12, 1994
    Flagstaff, Arizona
September 7-9, 1994
    Fort Collins, Colorado
September 29, 1994
    Albuquerque, New Mexico
October 18-19, 1994
    Phoenix, Arizona
February 13-17, 1995
    Phoenix, Arizona
June 19-23, 1995
    Phoenix, Arizona
July 17-21, 1995
    Flagstaff, Arizona
August 14-18, 1995
    Albuquerque, New Mexico

APPENDIX C

SCHEDULE OF FIELD VISITS

DATE	PLACE	COORDINATOR
April 4, 1993	Walnut Canyon/Bar M Canyon, Coconino NF, Arizona	Joe Ganey, Heather Green
May 20, 1993	Huachuca, Santa Rita and, Patagonia Mountains, Arizona	Russell Duncan Steve Spiech
June 23, 1993	Sacramento Mountains, Lincoln NF, New Mexico	Danney Salas Pat Ward
August 8, 1993	Overflight, Gila NF, New Mexico	Bruce Anderson Steve Servis
August 20, 1993	Fort Apache Indian Reservation, Arizona	Joe Jojola
April 4, 1994	Sierra Fria, Aguascalientes, Mexico	National Wildlife Council
May 11-13, 1994	San Carlos Apache Indian Reservation, Arizona	Steve Thompson Tim Wilhite
May 5, 1994	Zion National Park, Utah	Sarah Rinkevich

APPENDIX D

A REFERENCE FOR ENGLISH AND LATIN NAMES

English names were used in the text of this Recovery Plan to make smoother reading and to improve comprehension among people who are not familiar with Latin names. Names are arranged in alphabetical order of families for plants because this is the conventional way of arranging them in most commonly accessible tree and wildflower manuals. Species within the families are listed alphabetically by Latin names. Animal names are listed phylogenetically, or taxonomically, because this system prevails in most commonly accessible books of birds and mammals, the principal species reported here. Family names are also provided for the animals as an aid for further investigation.

PLANTS

Aceraceae

Canyon (Bigtooth) maple	*Acer grandidentatum*
Boxelder	*Acer negundo*

Chenopodiaceae

Shadscale	*Atriplex* sp.

Cupressaceae

Arizona cypress	*Cupressus arizonica*
Juniper	*Juniperus* sp.

Ericaceae

Madrone	*Arbutus* sp.
Manzanita	*Arctostaphylos* sp.

Fabaceae

Mesquite	*Prosopis* sp.

Fagaceae

Arizona white oak	*Quercus arizonica*
	Quercus chihuahuensis
	Quercus coccolobifolia
Emory oak	*Quercus emoryi*
Gambel oak	*Quercus gambelii*
	Quercus gentryi
Gray oak	*Quercus grisea*
Silverleaf oak	*Quercus hypoleucoides*
	Quercus laeta
	Quercus potosina
	Quercus resinosa
Netleaf oak	*Quercus rugosa*
Wavyleaf oak	*Quercus undulata*

Papilionoideae

New Mexico locust	*Robinia neomexicana*

Pinaceae

White fir	*Abies concolor*
Blue Spruce	*Picea pungens*
Pinyon pine	*Pinus edulis*
Limber pine	*Pinus flexilis*
Western white pine	*Pinus monticola*
Ponderosa pine	*Pinus ponderosa*
Aztec pine	*Pinus teocote*
Southwestern white pine	*Pinus strobiformis*
Douglas-fir	*Pseudotsuga menziesii*
Redwood	*Sequoia sempervirens*

Platanaceae

Arizona Sycamore	*Platanus wrightii*

Salicaceae

Narrowleaf cottonwood	*Populus angustifolia*
Trembling aspen	*Populus tremuloides*

Viscaceae

Dwarf mistletoe	*Arceuthobium* sp.

Zygophyllaceae

Creosotebush	*Larrea* sp.

ANIMALS

INVERTEBRATES

Tortricidae

Western spruce budworm	*Choristoneura occidentalis*

Scolytidae

Round-headed beetle	*Dendroctonus adjunctus*

Danaidae

Monarch Butterfly	*Danaus plexippus*

VERTEBRATES

Birds

Accipitridae

Golden eagle	*Aquila chrysaetos*
Northern goshawk	*Accipter gentilis*
Red-tailed hawk	*Buteo jamaicensis*

Strigidae

Great horned owl	*Bubo virginianus*
Spotted owl	*Strix occidentalis*
California spotted owl	*S. o. occidentalis*
Mexican spotted owl	*S. o. lucida*
Northern spotted owl	*S. o. caurina*
Barred owl	*Strix varia*
Fulvous owl	*Strix fulvescens*
Tawny owl	*Strix aluco*

Psittacidae

Yellow-headed parrot	*Amazona ochrocephala*

Mammals

Soricidae

Masked shrew	*Sorex cinereus*
Vagrant shrew	*Sorex vagrans*
Montane shrew	*Sorex monticouls*
Dusky shrew	*Sorex obscurus*
Water shrew	*Sorex palustris*

Leporidae

Desert cottontail	*Sylvilagus audubonii*
Eastern cottontail	*Sylvilagus floridanus*
Nuttall's cottontail	*Sylvilagus nuttallii*

Sciuridae

Northern flying squirrel	*Glaucomys sabrina*
Golden-mantled ground squirrel	*Spermophilus lateralis*
Rock squirrel	*Spermophilus variegatus*
Gray-collared chipmunk	*Tamias cinereicollus*
Gray-footed chipmunk	*Tamias canipes*
Least chipmunk	*Tamias minimus*
Cliff chipmunk	*Tamias dorsalis*
Red squirrel	*Tamiasciurus hudsonicus*

Geomyidae

Botta's pocket gopher	*Thomomys bottae*
Southern pocket gopher	*Thomomys umbrinus*
Northern pocket gopher	*Thomomys talpoides*

Heteromyidae

Great Basin pocket mouse	*Perognathus parvus*

Muridae

Pinyon mouse	*Peromyscus truei*
Brush mouse	*Peromyscus boylei*
Canyon mouse	*Peromyscus crinitis*
Rock mouse	*Peromyscus difficilis*
Deer mouse	*Peromyscus maniculatus*
White-footed mouse	*Peromyscus leucopus*
Bushy-tailed woodrat	*Neotoma cinerea*
Desert woodrat	*Neotoma lepida*

Mexican woodrat	*Neotoma mexicana*
Stephens woodrat	*Neotoma stephensi*
White-throated woodrat	*Neotoma albigula*
Long-tailed vole	*Microtus longicaudus*
Meadow vole	*Microtus pennsylvanicus*
Mexican vole	*Microtus mexicanus*
Montane vole	*Microtus montanus*

Dipodidae

Meadow jumping mouse	*Zapus hudsonius*
Western jumping mouse	*Zapus princeps*

Mustelidae

Long-tailed weasel	*Mustela frenata*

Trichechidae

Manatee	*Trichechus manatus*

APPENDIX E

AGENCIES AND PERSONS COMMENTING ON DRAFT RECOVERY PLAN

Critical review of planning documents by those that must implement them and others with relevant expertise is essential to producing management plans that are scientifically credible and feasible to implement. This appendix lists agencies and persons who reviewed the draft Mexican Spotted Owl Recovery Plan and provided comments on the document. These comments are in large part responsible for production of a final Recovery Plan that the Recovery Team believes is much improved over the draft version. Many comments were directly responsible for Recovery Plan revision, while many comments that were not incorporated provoked considerable thought and lively discussion during the Recovery Plan-revision period. The Recovery Team is grateful to those who spent valuable time contributing to this final Recovery Plan.

PEER REVIEW

The following persons were specifically asked to review the draft Recovery Plan or portions thereof, as indicated. "Parts Reviewed" referred to below relates to the draft Recovery Plan, not this document. Each persons' affiliation is listed. In addition, scientific and professional organizations that requested an individual's review are so indicated.

Commentor	Parts Reviewed	Affiliation	Organization
Forsman, E.D	All	Pacific Northwest Research Station, U.S. Forest Service Corvallis, OR	American Ornithologists' Union
Gutiérrez, R.J.	I, II	Humboldt State University Arcata, CA	
Holthausen, R.	I,II, III	U.S. Forest Service Corvallis, OR	
King, R.	II, III	Rocky Mountain Forest and Range Experiment Station U.S. Forest Service Fort Collins, CO	
LaHaye, W.	II.F, II.G	Humboldt State University, Arcata, CA	
Meslow, E.C.	All	Wildlife Management Institute Corvallis, OR	The Wildlife Society; Wildlife Management Institute
Morrison, M.L.	II.G, II.H	University of Arizona Tucson, AZ	

Commentor	Parts Reviewed	Affiliation	Organization
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Raphael, M.G.	I, II, III	Pacific Northwest Research Station, U.S. Forest Service Olympia, WA	
Stacey, P.	II.F, II.G, III	University of Nevada Reno, NV	
Verner, J.	II.G, III	Pacific Southwest Research Station, U.S. Forest Service Fresno, CA	

AGENCY REVIEW

The following agencies provided comments on the draft Recovery Plan. Federal agencies are listed first, followed by State and County agencies. Agency name is followed by signator; other reviewers are listed in ( ) when identified by the agency.

National Park Service, Southern Arizona Group; Jerry Belson, General Superintendent. (Benson, L.).

U.S. Bureau of Indian Affairs, Albuquerque Area Office; Patrick A. Hayes, Area Director. (Schwab, B.).

U.S. Bureau of Indian Affairs, Southern Ute Agency; Charles A. Recker, Superintendent. (Friedley, J.; Recker, T.).

U.S. Bureau of Land Management, Utah; Mat Millenbach, State Director. (Stringer, W.).

U.S. Fish and Wildlife Service, Arizona Ecological Services State Office; Sam F. Spiller, State Supervisor. (James, M.; Muiznieks, B.; Palmer, B.).

U.S. Fish and Wildlife Service, New Mexico Ecological Services State Office; Jennifer Fowler-Propst, State Supervisor. (Torres, C.).

U.S. Fish and Wildlife Service, Mountain-Prairie Region; James M. Lutey, Acting Assistant Regional Director, Ecological Services.

U.S. Forest Service, Southwestern Region; Charles W. Cartwright, Jr., Regional Forester. (Beyerhelm, C.; Birkland, C.; Briggs, A.; Brown, A.; Casper, L.; Cassidy, R.; Dargan, C.; Deaver, R.; DeLorenzo, D.; Derby, J.; Ellenwood, J.; Ewers, S.; Fletcher, R.; Gerritsma, J.; Green, H.; Herron, M.; Higgins, B.; Holbrook, C.; Hollis, H.; Holmstrom, D.; Johnson, D.; Kill, D.; Lucero, L.; MacIvor, J.; Madril, A.; Manthei, M.; Martinez, J.; Menasco, K.; Nelson, J.; Randall-Parker, T.; Rethlake, K.; Rolf, J.; Schaal, L.; Shafer, J.; Sheppard, G.; Spoerl, P.; Stahn, R.; Taylor, C.; Vigil, G.; Wistrand, H.; Zumwalt, M.).

U.S. Forest Service, Intermountain Region; Dale N. Bosworth, Regional Forester. (Botts, J.; Egnew, A.; Grandison, K.; Gray, S.; Hayman, R.).

U.S. Forest Service, Rocky Mountain Region: Elizabeth Estill, Regional Forester. (Player, R.).

Arizona Game and Fish Department: Duane L. Shroufe, Director. (Johnson, T.).

Arizona State Land Department: M. Jean Hassell, Commissioner.

Otero County Commission: Richard L. Zierlein, Chairman.

San Juan County Commission: Ty Lewis, Chairman.

OTHER GROUPS AND INDIVIDUALS

Applied Ecosystem Management, Flagstaff, AZ: Tod Hull. (On behalf of: Northern Arizona Loggers Association; Precision Pine and Timber Company; Reidhead Brothers Lumber Company; Stone Forest Industries).

Defenders of Wildlife, Washington, DC: Robert M. Ferris, Director, Species Conservation Division; Gregory J. Sater, Wildlife Counsel, Legal Division.

Forest Conservation Council, Santa Fe, NM: John Talberth, Executive Director.

Southwest Center for Biological Diversity, Silver City, NM: Kieran Suckling, Executive Director. (Attachment signed by Dennis Morgan, Research Associate, Southwest Center for Biological Diversity; Kieran Suckling, Executive Director, Southwest Center for Biological Diversity; Sharon Galbreath, Chairperson, Grand Canyon Chapter, Sierra Club; Samuel Hitt, Director, Forest Guardians; Joanie Berde, Carson Forest Watch; Tom Ribe, Public Forestry Foundation; Tom H. Wootten, Conservation Chair, Mesilla Valley Audubon Society; Mary Lou Jones, Zuni Mountain Coalition; Joseph Feller; Dave Henderson, Southwest Forest Alliance; Charles Babbitt, President, Maricopa Audubon Society; John Talberth, Executive Director, Forest Conservation Council; Jim Powers, Prescott National Forest Friends; Gary Simpson, Northern New Mexico Chapter, Wilderness Watch; Eleanor G. Wooten, Vice President, T & E, Inc.; Gwen Wardwell, Director, Rio Grande Chapter, Sierra Club; Mike Siedman; Jeff Burgess.).

Stone Forest Industries, Flagstaff, AZ: Steve C. Bennett, Regional Manager.

Mark Herron, Santa Fe, NM.

Terry Johnson, Los Alamos, NM.

Dennis R. Kingsbury, Munds Park, AZ.

Mexican Spotted Owl Recovery Plan
Supporting Documents

Volume II

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MEXICAN SPOTTED OWL RECOVERY PLAN
Volume II - Technical Supporting Information

This volume consists of chapters on aspects of Mexican spotted owl natural history that were developed during preparation of the Mexican Spotted Owl Recovery Plan (Recovery Plan). These treatises provide much of the information upon which the Recovery Plan, especially the recovery recommendations in Part III of Volume I, are based. Much of the material in Volume II is highly technical in nature and, although important, was not considered appropriate for inclusion in a working implementation document like Volume I of the Recovery Plan. The Mexican Spotted Owl Recovery Team and the Fish and Wildlife Service believe that these technical papers should, however, be available to anyone who would like a detailed account of subject matter contained herein.

Since the material detailed in Volume II was integral in developing the Recovery Plan, the salient points from each of the Volume II chapters are summarized in Part II of Volume I. This makes Volume I a stand-alone document containing the most relevant information needed to implement the Recovery Plan and understand the reasons behind the management recommendations contained therein.

Citations of material contained in this volume should read as follows:

[Author(s)] 1995. Pages [-] *in* USDI Fish and Wildlife Service. Mexican Spotted Owl Recovery Plan, Volume II.

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Gary C. White, Alan B. Franklin, and James P. Ward, Jr. .... 25 pages

Chapter 3: Landscape Analysis and Metapopulation Structure
Tim Keitt, Alan B. Franklin, and Dean Urban .... 16 pages

Chapter 4: Habitat Relationships
Joseph L. Ganey and James L. Dick, Jr. .... 42 pages

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James P. Ward, Jr. and William M. Block .... 48 pages

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CHAPTER 1: Distribution and Abundance of Mexican Spotted Owls

James P. Ward, Jr., Alan B. Franklin, Sarah E. Rinkevich,
and Fernando Clemente

Knowledge of the distribution and abundance of Mexican spotted owls can provide insight into the subspecies' geographic limits and habitat requirements. For example, standardized surveys for northern spotted owls among different habitats have provided evidence of the owl's affinity for older, densely layered forests (Forsman et al. 1977; 1987, Thomas et al. 1990, Blakesley et al. 1992). In addition, distribution and abundance patterns often provide a foundation for more intensive natural and life history studies.

For this recovery plan, we gathered and examined information on the distribution and abundance of Mexican spotted owls accumulated through 1993. We used this information to (1) document historical and current extent of this subspecies, (2) help formulate recovery unit boundaries, and (3) provide a template for landscape-scale analyses.

SOURCES OF INFORMATION

The quality and quantity of information regarding the distribution and abundance Mexican spotted owls varies by source. Historical accounts exist from museum collections and anecdotal observations by early natural historians from throughout the owl's range (reviewed in McDonald et al. 1991). These early observations are useful for documenting the owl's known historical range. However, haphazard and frequently unknown methods by which the historical information was obtained confound any attempt to infer change in the owl's abundance from historical to present time. Modern accounts exist from incidental observations provided by amateur and professional biologists and from organized surveys conducted by natural resource management or research personnel. Incidental observations are similar in quality to historical accounts, frequently lacking sufficient information for estimating population parameters or testing empirical hypotheses. However, when combined with results of planned surveys incidental observations can be used to document the current extent of the subspecies' range. Results from planned surveys and demographic studies have provided the best available data on the owl's abundance.

Planned surveys for Mexican spotted owls in the United States have been conducted by land-management agencies since 1989 and by researchers in Mexico since 1992. Survey protocols were reviewed in 1990 and a more formal program was subsequently developed to locate Mexican spotted owls (USDA Forest Service 1990). Owl demographic studies began in the Sky Island Mountains of Arizona in 1990 (Duncan et al. 1993), and in northern Arizona (Olson et al. 1993) and in the Tularosa Mountains of west-central New Mexico in 1991 (Seamans et al. 1993).

To document the current (1990-1993) distribution of the Mexican spotted owl, we defined an owl site as a visual sighting of at least one adult spotted owl or as a minimum of two auditory detections in the same vicinity in the same year. Observations prior to 1990 are considered historical records for the purposes of this report. The methods and limitations of these data are discussed further in the White et al. 1995.

HISTORICAL DISTRIBUTION

We compiled 600 and 35 historical records of Mexican spotted owls in the United States and Mexico, respectively (Table 1.1). We refer to these as records and not as independent sites because several observations may have been tallied for the same site. Incomplete information of the owls' locations prevented us from assigning each record to an individual site. Thus, these records cannot be used to estimate historical abundance and are presented only to show the approximate extent of the owl's distribution before 1990.

Table 1.1. Historical records and minimum numbers of Mexican spotted owls found during planned surveys, and incidental observations by Recovery Unit and land ownership.

Recovery Unit	Number of owl records before 1990[a]	Number of owl sites 1990 - 1993
UNITED STATES		
Colorado Plateau		
FS	21	16
BLM	6	10
NPS	34	23
Tribal	20	13[b]
New Mexico State	1	0
Unknown[c]	5	0
Subtotal	**87**	**62**
Southern Rocky Mountains - Colorado		
FS	2	8
BLM	0	6
NPS	0	0
Tribal	1	--[b]
Unknown[c]	17	0
Subtotal	**20**	**14**
Southern Rocky Mountains - New Mexico		
FS	25	34
NPS	3	0
New Mexico State	1	0
Private	4	0
Unknown[c]	8	0
Subtotal	**41**	**34**
Upper Gila Mountains		
FS	138	424
BLM	5	0
NPS	5	0
Tribal	20	--[b]
Private	1	0
Unknown[c]	104	0
Subtotal	**253**	**424**
Basin and Range - West		
FS	82	97
NPS	13	0
Tribal	0	--[b]
DOD	9	6
Private	8	0
Unknown[c]	57	0
Subtotal	**169**	**103**

Table 1.1. (continued)

Recovery Unit	Number of owl records before 1990[a]	Number of owl sites 1990 - 1993
UNITED STATES, continued		
Basin and Range - East		
FS	18	111
BLM	1	0
NPS	6	10
Tribal	2	--[b]
FWS	1	0
Private	2	0
Subtotal	**30**	**121**
United States Total	**600**	**758**
MEXICO		
Sierra Madre Occidental - Norte		
Sonora	8	9
Chihuahua	10	8[d]
Sinaloa	1	0
Subtotal	**19**	**17**
Sierra Madre Oriental - Norte		
Coahuila	2	0
Sierra Madre Occidental - Sur		
Durango	2	0
Aguascalientes	0	1[d]
Zacatecas	0	0[d]
San Luis Potosi	1	0
Guanajuato	1	0
Subtotal	**4**	**1**
Sierra Madre Oriental - Sur		
Coahuila	4	0
Nuevo Leon	4	1
Tamaulipas	0	0[d]
Subtotal	**8**	**1**
Eje Neovolcanico		
Jalisco	1	0
Colima	1[e]	0
Michoacan	1	0
Puebla	1[e]	0
Subtotal	**2**	**0**
Mexico Total	**35**	**19**

[a] Values do not connote numbers of owls nor owl sites because multiple records may exist from the same site through time.

[b] Additional owls are known to exist on many Tribal lands but the exact number is unavailable.

[c] Locations of these records were insufficient for assigning a land ownership.

[d] Additional sightings have been reported from 1994 surveys.

[e] Unverified record not included in totals (see text).

The general vicinity of all historical records is presented in the following section according to RU and land ownership. This information should help land managers to identify areas that may be occupied by Mexican spotted owls. Historical records for owls in the United States were compiled from several sources which are cited below. In contrast, much of the historical information for Mexico was taken from a comprehensive summary by Williams and Skaggs (1993).

Colorado Plateau Recovery Unit

Prior to 1990, Mexican spotted owls were recorded from Zion (Kertell 1977, Rinkevich 1991), Canyonlands, Capitol Reef (Sue Linner, FWS, Salt Lake City Utah, pers. comm.), Mesa Verde (Reynolds and Johnson 1994), and Grand Canyon National Parks (McDonald et al. 1991), Glen Canyon National Recreation Area (Behle 1960), and the Cedar City, Richfield, and Vernal Districts of the BLM (Behle 1981; Sue Linner, FWS, Salt Lake City, Utah, pers. comm.). Table 1.1 presents more detail regarding these records. The physical attributes of these historical owl sites include steep-sided, narrow-walled, or hanging canyons. The biotic attributes include coniferous overstory in canyon bottoms with an understory comprised by Gambel oak, bigtooth maple, boxelder, and scattered aspen groves near water (McDonald et al. 1991).

Historical accounts also place the Mexican spotted owl on the Kaibab Plateau in Arizona (Ganey and Balda 1989, North Kaibab Ranger District, unpublished data), plus many sites in New Mexico. These sites include Fence Lake (State), Frances Canyon (BLM), the Zuni Mountains and Mount Taylor (Cibola NF), and within the Zuni and Navajo Nations (McDonald et al. 1991, New Mexico Natural Heritage Data Base, Nature Conservancy, Albuquerque, NM). Generally, vegetation types reported for these areas include montane coniferous forests within canyon settings. The owl has been observed in steep-walled canyons with minimal vegetation as well as in forested, steep-sloped canyons on Black Mesa and in the Chuska Mountains.

Southern Rocky Mountains - Colorado Recovery Unit

Eighteen historical records of spotted owls exist within this unit (Webb 1983, Reynolds 1989). Most of these owls were found along the Colorado Front Range extending northward to Fort Collins. Two additional observations, one each from Rio Grande and San Juan National Forests, plus one from the Southern Ute Reservation were recorded during 1989 surveys (Reynolds and Johnson 1994; Table 1.1).

Historical owl locations in this recovery unit occurred in steep-sided canyons. These canyons are typically broader with walls that are not as vertical as sites occupied by owls in southern Utah (Colorado Plateau RU). Northern aspects of these canyons contain mixed-conifer forest, while southern aspects contain ponderosa pine and pinyon-juniper. Canyon bottoms contain Gambel oak and boxelder. Owl sightings in southwestern Colorado were generally in canyons that cut into mesas covered with pinyon and juniper. These canyon bottoms contained mixed-conifer or ponderosa pine-Gambel oak forests (McDonald et al. 1991).

Southern Rocky Mountains - New Mexico Recovery Unit

Mexican spotted owls are known historically (Table 1.1) from private and National Forest lands in the San Juan, Sangre de Cristo, and Jemez Mountains, and near Taos and Sante Fe, New Mexico (Johnson and Johnson 1985, McDonald et al. 1991). Incidental observations between 1979 and 1984 established the presence of the owl at nine additional sites in the Jemez Mountains, Sante Fe National Forest (Johnson and Johnson 1985). The owl has also been observed in Bandelier National Monument and near Morhy Lake on State lands (Johnson and Johnson 1985). Historical spotted owl locations throughout all of New Mexico (including the Basin and Range - East RU) have been described as "deep, narrow, timbered canyons with cool shady places, at elevations ranging from 6,500 [1,982 *sic*] to 9,000 ft [2,744 m]." (McDonald et al. 1991, after Ligon 1926).

Upper Gila Mountains Recovery Unit

Prior to a statewide survey conducted from 1984 through 1988, only one Mexican spotted owl was recorded from the northern Arizona (San Francisco Peaks) portion of this RU (Huey 1930). In contrast, several owls were reported for the National Forest lands in the Mogollon Highlands of east-central Arizona and west-central New Mexico (Ligon 1926, Skaggs 1988). Forests in those reports include the Apache-Sitgreaves, Gila, and Cibola National Forests (Table 1.1). A few observations were also recorded on BLM land near Bitter Creek, Grant County and at the Gila Cliff Dwellings National Monument (NPS), both in New Mexico. Following their survey of Arizona, Ganey and Balda (1989) reported 69 sites in the Arizona portion of the Mogollon Rim and in northern Arizona, including the Coconino, Kaibab, Tonto, and Apache-Sitgreaves National Forests. Another 44 records exist in the Arizona Heritage Data Base (Arizona Game and Fish Department, Phoenix, AZ). However, the latter records are distributed among habitats similar to those reported by Ganey and Balda (1989) and include several of the same sites.

Site characteristics for the historical Arizona locations (Ganey and Balda 1989) reflect the features described for other RU's: mountain slopes with mixed-coniferous forest, steep-walled canyons, or ponderosa pine-Gambel oak forest at elevations ranging from 1,525 to 2,925 m (5,000 to 9,590 ft). In southern New Mexico, Skaggs (1988) found cliffs present at 15 of the 18 historical sites which he examined. However, it is unclear how many of these sites were located in the Upper Gila Mountains RU. Skaggs (1988) also noted a well developed understory of bigtooth maple and Gambel oak dominated by mixed-conifer.

Basin and Range - West Recovery Unit

Historical records for Mexican spotted owls in this RU include observations in the Huachuca and Chiricahua Mountains during the 1890s (reviewed in McDonald et al. 1991). These birds were observed in a foothills-oak woodland and in a fir tree in Pinery Canyon, respectively. Two other sightings were recorded in lowland riparian communities including an owl nesting in cottonwoods northwest of Tucson in 1872 and near the Salt River in 1910 (Bendire 1892, Phillips et al. 1964, McDonald et al. 1991).

More recent surveys found the owl occurring at 84 sites throughout southern Arizona (Ganey and Balda 1989). Owls were located in rocky canyons or in several forest types at elevations ranging from 1,125 to 2,930 m (3,690 to 9,610 ft) in the Atascosa-Pajarito, Santa Rita, Santa Catalina, Patagonia, Whetstone, Galiuro, Huachuca, Chiricahua, Pinaleno, Superstition, Sierra Ancha, Mazatzal, and Bradshaw Mountains, Arizona. Below 1,300 m (4,264 ft), spotted owls were found in steep canyons containing cliffs and stands of live oak, Mexican pine and broad-leaved riparian vegetation (Ganey and Balda 1989). Above 1,800 m (5,904 ft) owls were found in mixed-conifer and pine-oak forests. Mid-elevation observations included sites with Arizona cypress and the other forest types previously mentioned. The Arizona Heritage Data Base reports 78 additional records in many of the same mountain ranges from 1974 to 1989. Historical records on private land include observations near Animas Peak, Black Bill Spring, and at the Gray Ranch, in New Mexico (Skaggs 1988).

Basin and Range - East Recovery Unit

Historical locations of Mexican spotted owls occur on lands of several jurisdictions in New Mexico: the Organ Mountains and near Bitter Creek (BLM); the Sandia, Manzano, Sacramento, and Guadalupe Mountains in the Cibola and Lincoln National Forests; and Carlsbad National Park (Skaggs 1988). The owl has also been found in Guadalupe National Park and on private land in the Davis Mountains of Texas (McDonald et al. 1991, Steve Runnels, The Heard Natural Science Museum and Wildlife Sanctuary, McKinney, TX, pers. comm.). One observation each was also reported on the lands of the Mescalero Apache and at the Santo Domingo Pueblo (New Mexico Natural Heritage Data Base, Nature Conservancy, Albuquerque, NM). Physical and biotic characteristics were not documented for these various sites. However, minimal notations describe mixed-conifer forests on eastern slopes of the Sacramento Mountains (Skaggs 1988). Canyons were mentioned for sites near the New Mexico-Texas border of the Guadalupe Mountains (McDonald et al. 1991).

Sierra Madre Occidental - Norte Recovery Unit

More than half of all historical records of Mexican spotted owls occurring in Mexico have been reported in this Recovery Unit (Table 1.1). Owls have been recorded from eight locations in the State of Sonora prior to 1990. These birds occurred in the Sierras Pinitos, Azul, de los Ajos, San Luis, Aconchi, Oposura, and Huachinera (Williams and Skaggs 1993). The eighth record was reported from a ridge north of La Mesa, Mexico. All of these areas are physiographically and biotically similar to the Sky Island Mountains of southeastern Arizona (Cirett and Diaz 1993). General elevations at or near these sightings range from 1,950-2,340 m (6,500 to 7,800 ft). Descriptions of sites at or near the recorded owls vary. Some descriptions include dense oaks, pine forest, pine-oak woodland, cliffs, and a spring with alders and sycamores (Williams and Skaggs 1993).

Ten historical records have been reported from the State of Chihuahua (Table 1.1). Owls have been collected, observed, or heard near Sierra Carcay, Arroyo Tinaja, Pacheco, Sierra Azul, Colonia Garcia, Sierra del Nido, Rancho La Estancia, Yaguirachic, Pinos Altos, and Vosagota (Williams and Skaggs 1993). Elevations at or near these sightings range from 1,710-2,700 m (5,700 to 9,000 ft). Most of these observations were made in or near pine-oak woodlands (Williams and Skaggs 1993). Owls have also been reported in canyons with oaks and madrone, and in subalpine forest comprised of Douglas-fir, true firs, oak, alder, pines, and chokecherry.

In Sinaloa, one spotted owl was observed near Rancho Liebre Barranca (Williams and Skaggs 1993). This area consists of deeply dissected barrancas with pine and oak forest at higher altitudes and a mixture of temperate and tropical forest in canyon bottoms.

Sierra Madre Oriental - Norte Recovery Unit

Spotted owls have only been reported from two sites within this Recovery Unit. Both records are from the Sierra la Madera of central Coahuila (Table 1.1). One owl was observed roosting in a "cliff-lined canyon bottom under a dense canopy of maples and oaks" in Canada el Agua (Williams and Skaggs 1993). Another owl was observed and heard in a "garden-like" arroyo containing pines, oaks, and madrones (Williams and Skaggs 1993). Elevations of these observations were approximately 1,900 and 2,100 m (6,200 and 7,000 ft), respectively.

Sierra Madre Occidental - Sur Recovery Unit

Four historical records exist from the States of Durango, San Luis Potosi, and Guanajuato (Table 1.1). In Durango, spotted owls have been observed near Espinazo del Diablo in mixed-conifer forest and on two occasions in the Michilia Biosphere Reserve. One of the owls found in the reserve was observed roosting in a large oak that was in a cool, wet ravine. The second owl was found in a pine-oak forest. Remaining records are of two spotted owls collected at approximately 2,400 m (8,000 ft) near Cerro Campanario, San Luis Potosi, and another that was collected in the State of Guanajuato (Williams and Skaggs 1993).

Sierra Madre Oriental - Sur Recovery Unit

In this Recovery Unit, eight records of spotted owls have been reported from two States, Coahuila and Nuevo Leon (Table 1.1). Owls have been heard and observed on several occasions east of Saltillo, Coahuila. Elevations of these records are generally higher than other historical sightings and range from 2,700-3,060 m (9,000 to 10,200 ft). The vegetation at these sites has been described as oak-pine-conifer woodland or as oak-pine woodland. Cliffs are present at all sites and chaparral or desert scrub vegetation can also be seen at two of these sites (Williams and Skaggs 1993). In addition, two of the four historical records from Nuevo Leon are from the mountains east of Saltillo and south of Monterrey. At one of these sites a spotted owl was heard calling from an oak-pine-conifer forest, approximately 2,550 m (8,500 ft) in elevation. The second was heard calling from an "oak-pine woodland mixed with Tamaulipan thorn woodland and scrub and palms on the canyon cliffs" (Williams and Skaggs 1993). The elevation at this site was 1,350 m (4,500 ft), the lowest to be recorded for spotted owls in Mexico. The remaining two Nuevo Leon records are from the slopes of Cerro Potosi (Williams and Skaggs 1993). One female spotted owl was collected at 2,250 m (7,500 ft) in 1946. Another owl was heard in 1978 from a pine woodland near the summit at 3,630 m (12,100 ft), the highest elevation recorded for a Mexican spotted owl.

Eje Neovolcanico Recovery Unit

Only two confirmed records of Mexican spotted owls exist for the southernmost Recovery Unit (Table 1.1). Specimens of spotted owls have been collected from the States of Jalisco and Michoacan. Two other records from the States of Colima and Puebla have been published (Enriquez-Rocha et al. 1993) but have not been verified (Williams and Skaggs 1993).

In Jalisco, the owls were found on the north slope of Cerro Nevado de Colima in a park-like pine forest with broad-leaved oaks, and mesic ground flora near 2,400 m (8,000 ft) elevation (Williams and Skaggs 1993). In Michoacan, the holotype of the subspecies and only existing State record was collected in 1903 from Cerro Tancitaro above 1,950 m (6,500 ft). Details regarding the spotted owls allegedly collected in Colima and Puebla have not been reported (Enriquez-Rocha et al. 1993). We mention these latter records because they suggest possible extensions of the owl's range. However, we have not included them in the totals presented in Table 1.1.

CURRENT DISTRIBUTION AND ABUNDANCE

Number of Sites

Surveys for Mexican spotted owls conducted from 1990 through 1993 indicate that the species persists in most locations reported prior to 1989. Notable exceptions include riparian habitats in the lowlands of Arizona and New Mexico, and all previously occupied areas in the southern States of Mexico. As a result of planned surveys, additional sightings have been reported for all recovery units. New locations will undoubtedly be reported following future surveys.

The current known range of the Mexican spotted owl extends north from Aguascalientes, Mexico, through the mountains of Arizona, New Mexico, and western Texas to the canyons of southern Utah, southwestern Colorado, and the Front Range of central Colorado (Figures 1.1 and 1.2). Results from planned surveys and incidental observations conducted during 1990 through 1993 indicate one or more owls have been observed at a minimum of 758 sites in the United States and 19 sites in Mexico (Table 1.1).

The greatest concentration of the known sites in the United States occurs in the Upper Gila Mountains Recovery Unit (55.9%) followed by the Basin and Range-East (16.0%), and Basin and Range-West (13.6%), Colorado Plateau (8.2%), Southern Rocky Mountains - New Mexico (4.5%), and Southern Rocky Mountains - Colorado (1.8%) Recovery Units. Thus, fewer owl sites are currently known to occur north of the Upper Gila Mountains Recovery Unit (12.7%) than to the south of this recovery unit (29.6%). In Mexico, the majority of spotted owls have been documented in the Sierra Madre Occidental - Norte RU (89.5%). However, the number of identified sites within a given RU depends on survey intensity for which we have little reliable data. Therefore, the percentages of sites within a given RU may not reflect the true relative abundance of Mexican spotted owls.

Figure 1.1. Recovery unit boundaries and current distribution of Mexican spotted owls in the United States based on planned surveys and incidental observations recorded from 1990 through 1993.

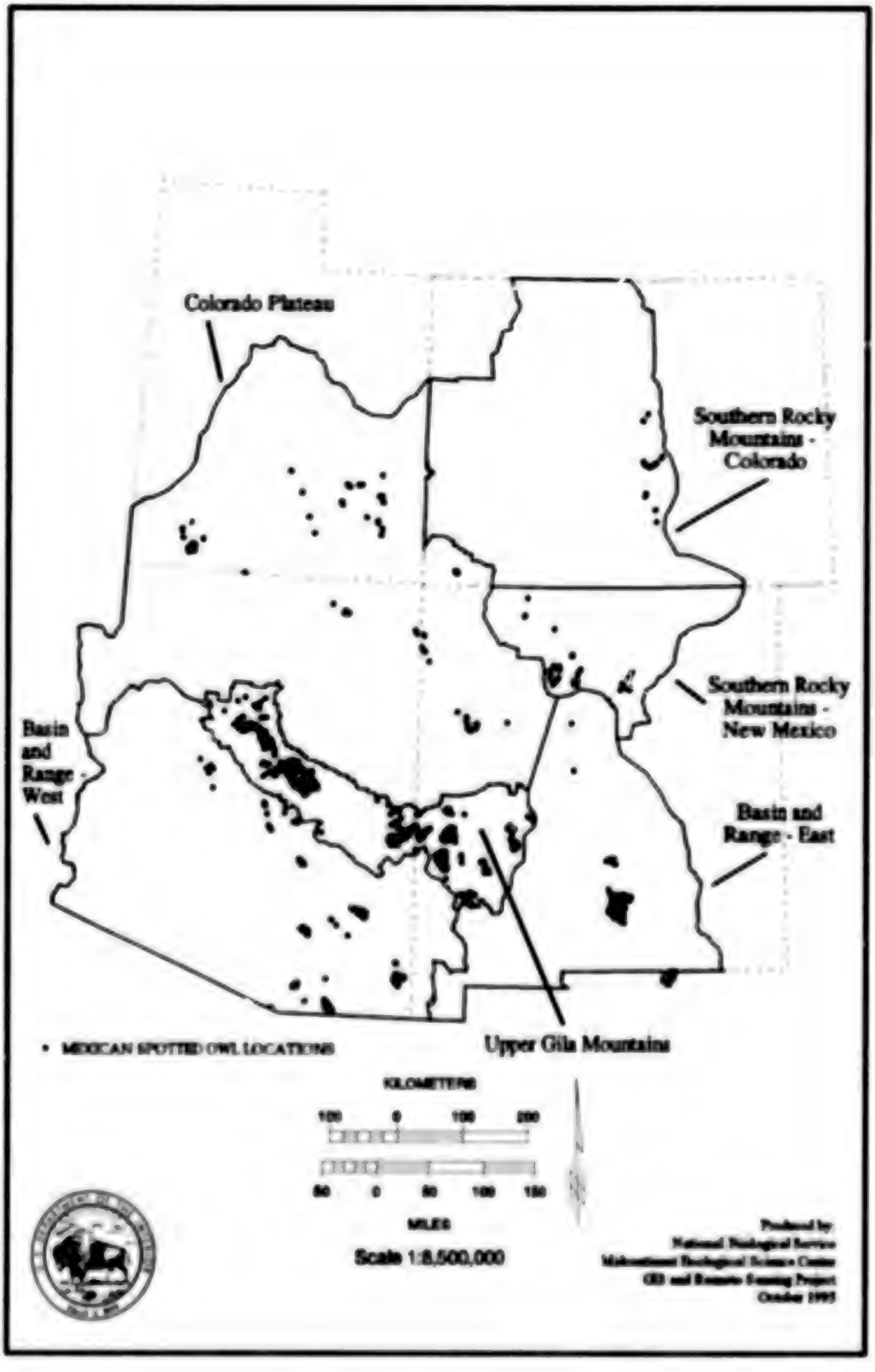
Colorado Plateau
Southern Rocky Mountains - Colorado
Southern Rocky Mountains - New Mexico
Basin and Range - West
Basin and Range - East
Upper Gila Mountains
• MEXICAN SPOTTED OWL LOCATIONS
KILOMETERS
100 0 100 200
50 0 50 100 150
MILES
Scale 1:8,500,000
Produced by
National Biological Service
Midcontinent Ecological Science Center
GIS and Remote Sensing Project
October 1995

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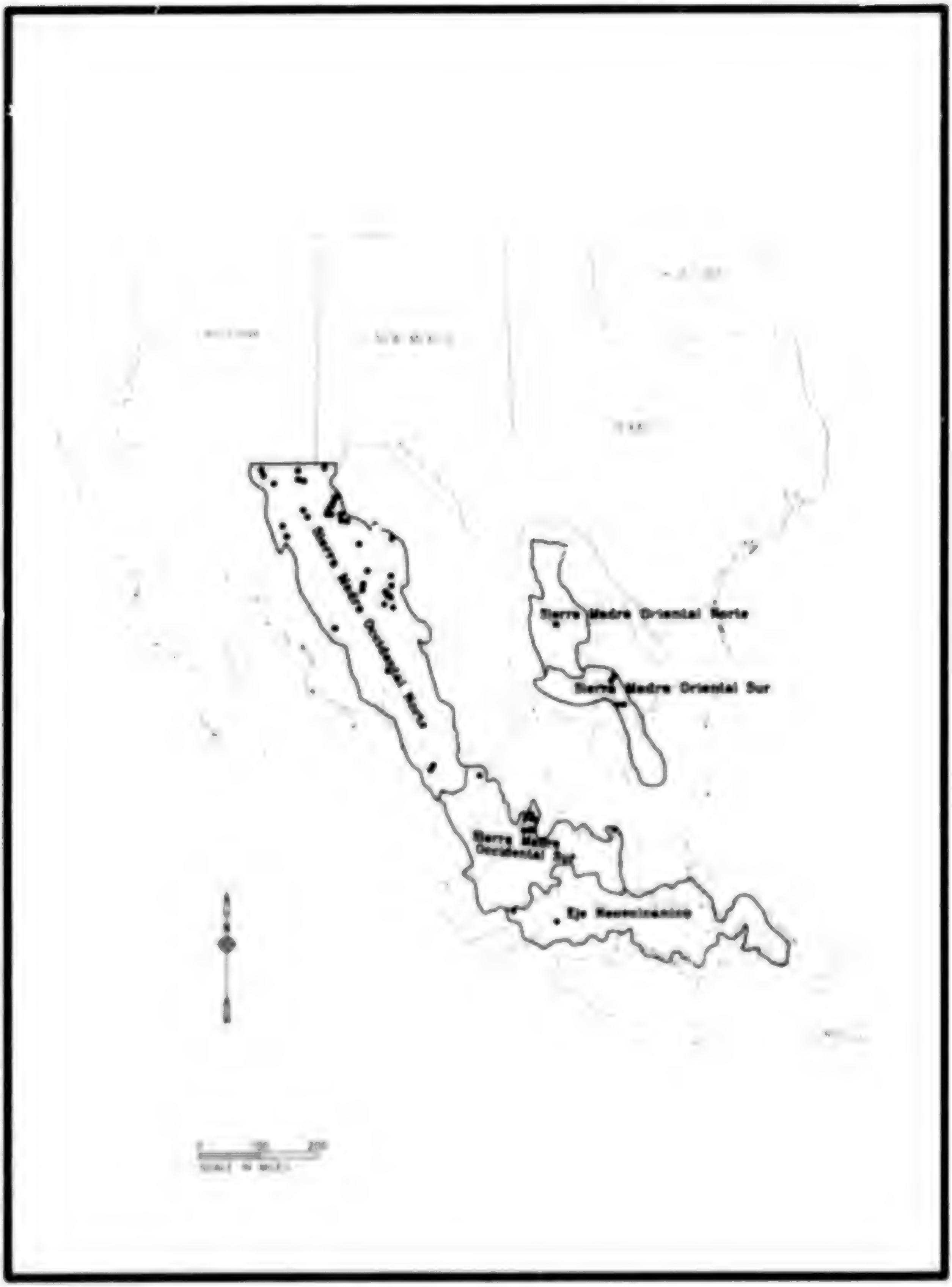
Figure 1.2. Current distribution of Mexican spotted owls in Mexico based on planned surveys and incidental observations recorded from 1990 through 1993.


Sierra Madre Occidental Norte
Sierra Madre Oriental Norte
Sierra Madre Oriental Sur
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Number of Owls

A reliable estimate of the number of Mexican spotted owls throughout its entire range is not available. Fletcher (1990) calculated that 2,074 owls existed in Arizona and New Mexico in 1990 using information gathered by the FS, Southwestern Region. McDonald et al. (1991) modified Fletcher's (1990) calculations reporting a total of 2,160 owls in the United States. If one assumes that all 758 sites included in this recovery plan were occupied by owl pairs, then at least 1,516 adult or subadult owls were known to exist in the United States and 38 adult or subadult owls in Mexico from 1990 through 1993. These numbers are not reliable estimates of current population size because no measures of bias or precision can be produced. Further, the amount of survey effort devoted to deriving these numbers cannot be reliably calculated, nor is an accurate measure available for areas or habitats surveyed. Thus, we did not believe it would be useful to estimate the size of the Mexican spotted owl population given the limited quality of data currently available. At best, our total numbers reported in Table 1.1 represent a range for the minimum number of owls known to exist during some portion of a four year period in the United States and Mexico (777 individuals if each site was occupied by a single owl to 1,554 individuals if each site was occupied by a pair).

Density

The abundance of any terrestrial organism is more appropriately presented as density, the number of individuals per unit of area (Caughley 1977), hereafter referred to as "crude density" (Franklin et al. 1990). Because the Mexican spotted owl occupies a variety of habitats throughout its range, ecological density, the number of individuals per area of usable habitat, (Tanner 1978) would be a more meaningful measure of abundance. At this time, rangewide estimates of either crude or ecological density of Mexican spotted owls cannot be provided for the same reasons that population numbers cannot be estimated reliably.

Two estimates of crude density ($\hat{D}$) exist from studies conducted at either end of the Upper Gila Mountains Recovery Unit. These estimates were reported for the Coconino Study Area (CSA) in northern Arizona and for the Gila Study Area (GSA) in west-central New Mexico by Gutiérrez et al. (1994). Density of adult and subadult owls in both studies was estimated using a count of individuals divided by the size of the study area (CSA: 484 km^2 [187 mi^2]; GSA: 323 km^2 [125 mi^2]). Identity of owls was established by capturing and marking or by direct observation at daytime roosts when marking was not possible. Methods were similar to those reported for northern spotted owls by Franklin et al. (1990) and Ward et al. (1991) and resulted only in density of territorial individuals. Only the 1993 estimates of density ($\hat{D}$) are presented here because the boundaries of the CSA study area were shifted between 1991 and 1992.

$\hat{D}$ of Mexican spotted owls in 1993 was 0.120 owls/km^2 (0.310 owls/mi^2) in the CSA and 0.180 owls/km^2 (0.464 owls/mi^2) in the GSA. The CSA has more ponderosa pine-Gambel oak forest (72.6%) and less mixed-conifer forest (14.4%) than the GSA (22.3% and 28.5%, respectively; Gutiérrez et al. 1994). The larger proportion of mixed conifer may partially explain higher owl density in the GSA. For comparison (Figure 1.3a), 1993 density of California spotted owls in the San Bernardino Mountains, California (LaHaye and Gutiérrez 1994) was 0.118 owls/km^2 (0.305 owls/mi^2) and density of northern spotted owls in northwestern California (Franklin, unpublished data) was 0.272 ± 0.004 (SE) owls/km^2 (0.703 ± 0.009 owls/mi^2). Survey methods used in these later two studies were identical to those used in the CSA and GSA. Naive density estimates, the number of owls counted divided by study area size, were used in this comparison (Figure 1.3a) except for the northern spotted owl population. In the latter case, a Jolly-Seber model was used to estimate numbers of owls and an associated sampling variance. The two density estimators are similar for spotted owls (Ward et al. 1991).

Combining the CSA and GSA density data and weighting by area provides an average estimate of 0.144 owls/km^2 (0.372 owls/mi^2)

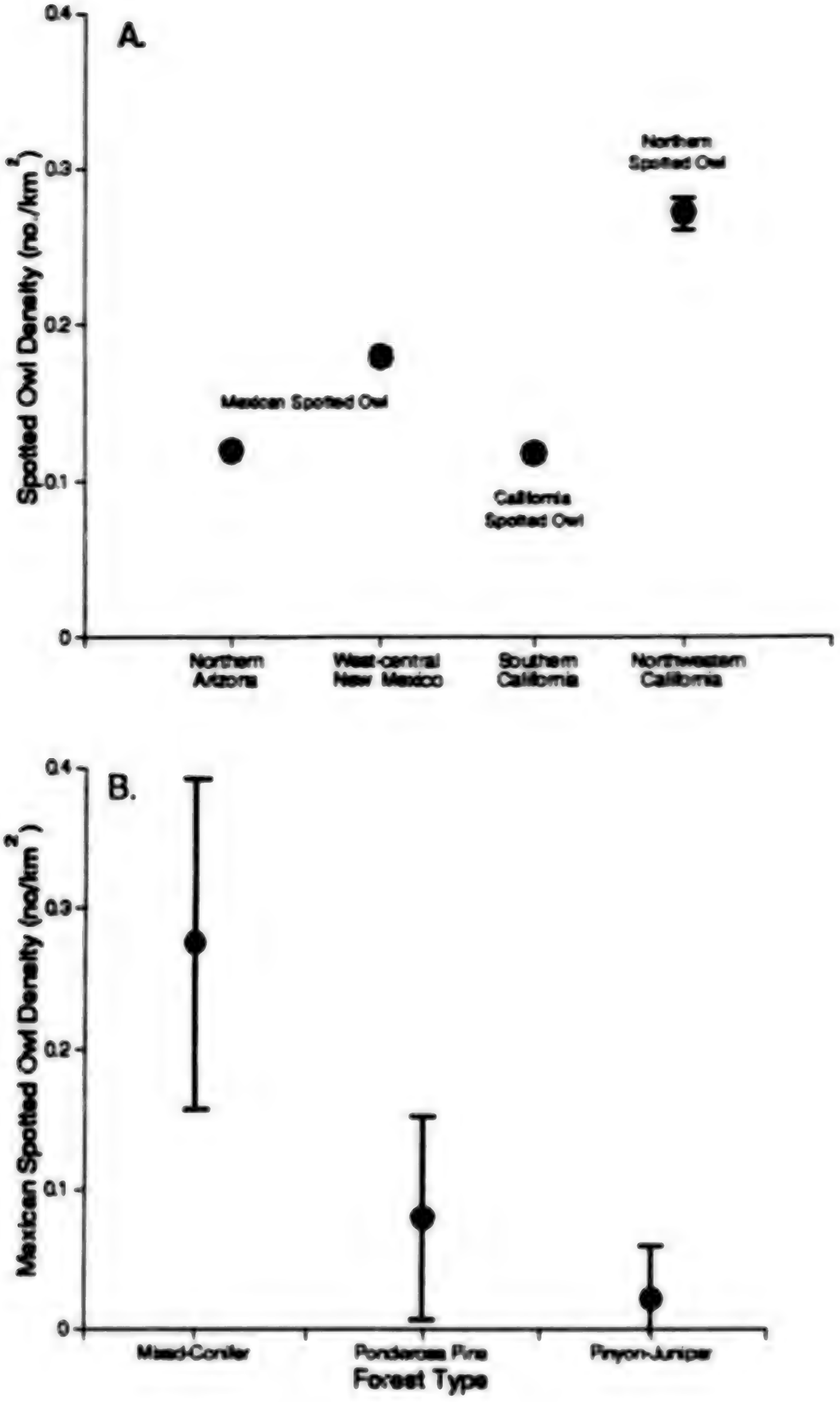

Figure 1.3. Density of **(a)** all three subspecies compared among regions and **(b)** Mexican spotted owls among three forest types in the Sacramento Mountains, New Mexico, based on Skaggs and Raitt (1988). Sources of estimates for northern Arizona (CSA) and west-central New Mexico (GSA) are from Gutiérrez et al. (1994); southern California are from LaHaye and Gutiérrez (1994); and northwestern California are from Franklin (unpublished data). Vertical bars are 95% confidence intervals.

within the Upper Gila Maintains RU. However, this estimate should not be extrapolated to a larger area because (1) the CSA and GSA were not randomly selected and (2) studies were not sufficiently replicated. Both of these problems could severely bias extrapolated estimates because the areas studied are not necessarily representative samples of the entire recovery unit or subspecies' range.

In another study, Skaggs and Raitt (1988) examined the density of Mexican spotted owls among three forest types in the Sacramento Mountains (Basin and Range - East RU). Eighteen 23.1- km^2 (9-mi^2) quadrats, six in each forest type, were surveyed for spotted owls. Quadrats were classified as pinyon-juniper woodland, pine, or mixed-conifer forest according to the most common tree species within the quadrat. Owl density averaged across the three forest types ($\bar{x} = 0.126$ owls/km^2 [0.325 owls/mi^2]) was similar to the average estimate from the two southwestern demographic studies. When partitioned by forest type, analysis of these data by the Team showed significantly higher densities ($F = 16.93$, df = 2, $P = 0.0001$) in the mixed-conifer ($\bar{x} = 0.275$ owls/km^2, SE = 0.046 [0.704 owls/mi^2, SE = 0.117]) compared to the pine-dominated ($\bar{x} = 0.080$ owls/km^2, SE = 0.028 [0.204 owls/mi^2, SE = 0.073]) and pinyon-juniper habitats ($\bar{x} = 0.022$ owls/km^2, SE = 0.036 [0.056 owls/mi^2, SE = 0.038]). Density was not statistically different between the latter two forest types (Figure 1.3b). Forest type explained 69.3% of the variation in owl density using this ANOVA model. Skaggs and Raitt (1988) showed similar results using density of sites rather than owl density.

CONCLUSIONS

The Mexican spotted owl currently occupies a broad geographic area, but it does not occur uniformly throughout its range. Instead, the owl occurs in disjunct localities that correspond to isolated mountain systems and canyons. This distribution mimics most historical locations, with a few exceptions. The owl has not been reported along major riparian corridors in Arizona and New Mexico where it historically occurred, nor in historically-documented areas of southern Mexico. Riparian communities and previously occupied localities in the southwestern United States and southern Mexico have undergone significant habitat alteration since the historical sightings (USDI 1994). However, the amount of effort devoted to surveying these areas is poorly known and future surveys may document spotted owls. Surveys conducted to relocate spotted owls have been unsuccessful in northern Colorado near Fort Collins and Boulder, where records exist from the early 1970s and 1980s, and in the Book Cliffs of east-central Utah where owls were recorded in 1958.

The majority of Mexican spotted owls currently known to exist occur in the Upper Gila Mountains Recovery Unit. This unit can be considered a critical nucleus for the subspecies because of its central location within the owl's range and its seemingly high density of owls. Other areas likely to be important include the Sky-islands of southeastern Arizona and the Sacramento Mountains, New Mexico (Basin and Range RUs). Throughout its range, most (91%) Mexican spotted owls occur on public land administered by the FS.

Density estimates of Mexican spotted owls contrasted among forest types in the Sacramento Mountains and between two areas in the Upper Gila Mountains RU suggest that mixed-conifer supports more owls compared to pine-oak, pine, and pinyon-juniper forest types. Mexican spotted owl densities reported from three areas are similar to those reported for California spotted owls occurring in the San Bernardino Mountains, California and slightly less than the density of northern spotted owls occurring in northwestern California.

Limited information inhibits reliable estimation of the absolute number of Mexican spotted owls. However, it is apparent from current patterns in distribution and habitat use that the subspecies is rare relative to other raptors and is distributed discontinuously throughout its range. Species existing under such conditions are considered vulnerable to extirpation (see Dawsen et al. 1987 for discussion relevant to spotted owls). Although future efforts will undoubtedly discover additional owls, the extent and total number of this subspecies in the United States will likely not change in magnitude enough to alter this conclusion. The contrary is true for Mexico where planned surveys have begun only recently.

Consequently, current strategies developed to conserve Mexican spotted owls will be limited to basic knowledge about the owl's distribution. More specific recommendations will require additional information on the total population size, population structure, or interactions among subpopulations.

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CHAPTER 2: Population Biology

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The development of recovery guidelines and criteria for Mexican spotted owl populations requires understanding the life history traits and population processes for this species. We examined the characteristics and trends of Mexican spotted owl populations at three spatial scales: range-wide, regional, and local. Range-wide scales correspond to characteristics and processes occurring across the U.S. geographic range of the subspecies. Regional scales correspond to recovery units that were delineated according to broad ecological patterns (see Rinkevich et al. 1995). Local scales roughly correspond to subpopulations that occur within each recovery unit. Ideally, the same population characteristics and processes should be examined over different temporal and spatial scales. However, temporal comparisons were restricted because historical information on Mexican spotted owl populations does not exist. Thus, we could not compare historical and current populations to assess the impacts of past and present management activities.

In this section, we first review the sources of information available for making inferences about Mexican spotted owl populations. We then quantitatively describe the life history characteristics of the owl using age- and sex-specific survival probabilities and fecundity rates. These characteristics were estimated from data collected during radio-telemetry studies, banding studies, and a regional FS monitoring program. We examined population trends first by estimating the finite rate of population change (λ) on a local scale using our estimates of survival and fecundity from selected studies and then by evaluating temporal trends in occupancy rates of FS management territories (MTs) on a regional scale. Finally, we attempted to examine relationships of vegetation type on reproductive output at a range-wide scale. Through this stepwise procedure, we evaluated the current state of Mexican spotted owl populations.

SOURCES OF INFORMATION

Since 1989, organized surveys for Mexican spotted owls have been conducted by personnel of the FS, BLM, NPS, Tribes, State wildlife agencies, and by private researchers. Most surveys followed the procedures described for the FS Region 3 (USDA Forest Service 1990). Under the FS Region 3 system, two types of surveys, inventory and monitoring, were conducted for different purposes. Inventories were general surveys used to detect the presence of spotted owls within a defined area. Monitoring specifically assessed temporal changes in site occupancy and reproduction by spotted owls in management territories (MT). Both procedures required adherence to a standard survey protocol. In addition, two types of monitoring, "formal" and "informal," were utilized, with formal monitoring following guidelines of USDA Forest Service (1990). MTs were monitored each year from 1989 through 1993 with the formal procedures if they had (1) no previous management activity, (2) activity 5-20 years prior to monitoring, or (3) recent activity within 5 years of monitoring. Formal monitoring resulted in more survey effort per MT than for informal monitoring (although some informal monitoring sites were visited more often than required by formal monitoring). Informal monitoring could be conducted at any site not formally monitored in any year. The greatest amount of effort for surveys was devoted to formal monitoring, followed by informal monitoring, and then inventory.

A limitation of the FS database was that the MTs surveyed were not randomly sampled from all possible MTs. MTs were added to the database as owls were found. We do not expect excessive bias in estimated fecundity or persistence (as defined in Life History Parameters section) from this nonrandom sample because these parameters are probably not directly linked to the sample selection procedures. We do expect significant biases in the estimates of density, abundance, and occupancy rate because including an MT in the sample is directly linked to these parameters.

In 1990, a study of Mexican spotted owl population dynamics was initiated in the Sky Islands of southeastern Arizona (Duncan et al. 1993). This study complemented inventory and monitoring efforts on the Coronado National Forest. In 1991, two other studies on population dynamics were initiated: one on the Coconino National Forest in northern Arizona (Gutiérrez et al. 1993, 1994) and the other on the Gila National Forest in west-central New Mexico (Gutiérrez et al. 1993, 1994). These two studies were conducted independently from inventory and monitoring efforts, and thus used methods different than the formal monitoring protocol. In all three population studies, owls were located, captured, individually marked for future recognition, and the number of fledged young were recorded. These population studies offer the most reliable information currently available for estimating abundance, rates of reproduction and survival, and for deriving short-term estimates of population change. However, inferences from these studies are somewhat limited because their study areas were not randomly selected from a defined sampling frame. Even with this limitation, estimates from these studies are useful in our preliminary evaluation of Mexican spotted owl population biology.

Most inventory and monitoring work was conducted by personnel of the FS Region 3. By direction (Forest Service Manual 2676.2), survey data were recorded on standard forms and maps following field observations. MTs were assigned using the survey results. Occupancy and reproductive status of Mexican spotted owls were summarized by MT at the close of each fiscal year (30 September). These summaries did not include all information recorded on field forms, such as that used to determine occupancy, reproductive status, or spatial coordinates of owl locations. Original data recorded on field forms were necessary for verifying occupancy and reproductive status. Without this type of verification, reliability of previous assignments cannot be demonstrated. Further, spatial coordinates compatible with a Geographic Information System (GIS) were required to document owl distribution and conduct habitat analyses at various spatial scales. Unfortunately, the original data and GIS-compatible coordinates were not entered into a computerized database. Thus, the Team attempted to compile and create its own database (referred to as the Team database) from original data forms and plotted locations to supplement summaries provided by the FS Region 3 Office (referred to as the FS database).

Attempts to create the Team database met with limited success. Entering a portion of the data forms by a professional data-entry service failed because standard codes and recording instructions were not followed by data collectors. Further, various details were not recorded and maps were missing. In a second attempt, the Team formed and trained a set of crews to visit FS Ranger Stations and Supervisor Offices to enter data from forms and maps and to record Universal Transverse Mercator (UTM) coordinates of owl locations associated with surveys. The same information was collected from land management agencies throughout the owl's range for the four-year period (1990-1993). Year-end summaries from the FS Region 3 were compared to output from the Team database to verify similarity for the period 1990-1993.

We found many discrepancies between the Team and FS Region 3 databases, the greatest being fewer territories with complete reproductive information in the Team's database. The FS database contained 1,984 records, whereas the Team's database contained only 377 observations where valid estimates of reproductive output (number of fledged young) were available. A valid estimate of reproductive output was one for which appropriate protocols (see Forsman 1983, USDA Forest Service 1990) substantiated the estimate or for which young were reported. Thus, we were able to locate only a fraction of the data presumably available.

When the two databases were merged, we found 11 records in the Team database that had no corresponding record in the FS database. Further, the FS database has no fecundity estimate for 45 records for which the Team's database had a valid fecundity estimate. Of the 321 records that matched, 271 records had identical values for reproductive output. Eight of the remaining records had greater values in the Team database, whereas 42 had greater values in the FS database. For the 321 matching records, the FS database had a significantly greater fledgling rate ($P < 0.001$) than the Team database. The expected bias was that the FS database would have a lower estimate of reproductive output because many of the records with zero young reported were not properly substantiated by mousing data as was done in the Team database. However, changes by the FS occurred during summarization procedures, among them selected territories with zero young recorded were changed to unconfirmed (Keith Fletcher, FS, Albuquerque, NM, pers. comm.). Therefore, the FS database has a higher estimate of reproductive output because a number of territories with valid values of zero were eliminated from the calculation. This would introduce an overestimate of reproductive output. Whether the two biases in the FS database cancel each other is unknown.

A potential problem with the Team database was the incomplete availability of data forms; many of the needed forms were missing. The last form used to complete the estimate of reproduction for many of the MTs may not have been available for data entry. As a result, the Team database has a lower estimate of reproduction than the FS database. The Team's effort to validate the FS estimates of fecundity does not accomplish this objective. Rather, the Team database appears too incomplete to be useful for estimating fecundity. Therefore, we have used estimates of fecundity from the FS database with the understanding that these estimates may be biased for two reasons: inadequate validation of the fecundity and occupancy results, and nonrandom sampling. The benefit of the Team obtaining raw data from the FS is that this effort has demonstrated severe problems with the handling of data collection, data management, and data analysis for the monitoring program. By discovering these problems, the problems are correctable in the future.

LIFE HISTORY PARAMETERS

An organism's life history is the combination of birth and death processes exhibited in its natural environment (Partridge and Sibley 1991). The optimal trade-off in survival and reproduction, resulting in fitness, should be maximized by the life history favored by natural selection. Under optimality theory, the organism's life history is a finely tuned result of adaptations to its environment; major perturbations to an organism's environment could eventually lead to its extinction. However, behavioral plasticity may allow organisms to adjust life-history strategies to current environmental conditions (Hansen and Urban 1992). When examining recovery of a species after past and present environmental perturbations of varying magnitudes, one must question whether that species will perish or persist. Therefore, examining the life history characteristics of the Mexican spotted owl is paramount to understanding how it responds to changes in its environment.

An organism's life history can be quantitatively described in terms of age- and sex-specific survival, age- and sex-specific fecundity rates, longevity, and age at first reproduction (Stearns 1992). In the following section, we outline current estimates of life history parameters for the Mexican spotted owl, using a variety of estimators calculated with different sources of data. These parameters can be used in two ways to make inferences about Mexican spotted owl populations: (1) to estimate the finite rate of population change (λ), and (2) to examine components of fitness within populations (Roff 1992).

Age- and Sex-Specific Survival

We estimated age- and sex-specific survival for Mexican spotted owls using mark-recapture estimators with data from banded owls in population studies, binomial survival estimators with data from radio-tagged owls studied at various locations, and survival estimators from data collected during the FS monitoring program. Where feasible, we recognized four age classes: juveniles (J), first-year subadults (S1), second-year subadults (S2) and adults (A), all as described by Forsman (1981) and Moen et al. (1991). Juveniles (age, $x = 0$ years) were fledged young-of-the-year. First-year subadults ($x = 1$ year), second-year subadults ($x = 2$ years), and adults ($x \geq 3$ years) have similar body plumage but were distinguished by different retrix characteristics (Moen et al. 1991). Not all studies differentiated the two subadult age classes, so these two age classes were usually lumped into a single subadult (S) age class for the purpose of estimating survival. We distinguished between subadults and adults because subadults usually have lower reproductive rates than adults.

Mark-recapture Survival Estimators from Population Studies

Mark-recapture estimators yield maximum likelihood estimates of apparent survival (ϕ) and recapture (or resighting) probability (p), which are asymptotically unbiased, normally distributed, and have minimum variance (Lebreton et al. 1992). An important consideration with apparent survival is that $1 - \phi$ = death + permanent emigration. For apparent survival to accurately reflect true survival (S), permanent emigration over the course of the study must be close to zero. Emigration is difficult to quantify, requiring the use of large samples of radio-marked birds.

Another limitation of the mark-recapture data is that only territorial birds are marked, because nonterritorial birds ("floaters") do not respond to the capture and sighting methods employed. Even though marked juveniles enter the floater population, they are not recaptured until they become territorial, which may not happen because they emigrate from the study area. Floaters that never become territorial are never included in the data to estimate survival, even if they remain on the study area. As a result, juvenile and subadult survival estimates produced from birds banded as juveniles are biased low because of the entry into the floater population and/or emigration from the study area. However, estimates of survival generated from subadults and adults marked as territorial birds, hence with negligible emigration, are unbiased if inference is only to territorial birds. Thus, inferences from the mark-recapture data only apply to the territorial population because only birds from the territorial population are marked.

We examined mark-recapture data from color-banded Mexican spotted owls derived from the three population study areas (Figure 2.1): (1) a 484-km^2 (187-mi^2) area located on the Coconino National Forest (Upper Gila Mountains RU) denoted as the CSA (Gutiérrez et al. 1994); (2) a 323-km^2 (125-mi^2) area located on the Gila National Forest (Upper Gila Mountains RU) denoted as the GSA (Gutiérrez et al. 1993); and (3) an area encompassing portions of the Sky Island Mountains in southeastern Arizona (Basin and Range - West RU) denoted as the SISA (Duncan et al. 1993). A total of 148 adult, 44 subadult, and 238 juvenile capture histories compiled during 3- and 4-year periods were utilized in the subsequent analyses (Table 2.1).

Methods used to estimate survival from the mark-recapture data are detailed in Burnham et al. (1994) and Lebreton et al. (1992). Two sets of parameters are estimated with these models: ϕ is the probability of a bird remaining alive and on the study area, and p is the probability that the bird will be resighted after initial capture. Both ϕ and p are indexed to provide specific estimates with respect to time, age, sex, and area. We employed three analyses: (1) goodness-of-fit testing to the Cormack-Jolly-Seber (CJS) models using computer program RELEASE (Burnham et al. 1987) and JOLLY (Pollock et al. 1990); (2) examination of a wide variety of models progressing from a biologically realistic global model to the simplest model using program SURGE (Lebreton et al. 1992); and (3) selection of the most parsimonious model with Akaike's Information Criteria (AIC) and likelihood ratio tests (LRT) (Lebreton et al. 1992).

Goodness-of-fit tests of data to the CJS model include Test 2, which tests primarily for lack of independence, and Test 3, which primarily tests for heterogeneity in survival and recapture probabilities (Burnham et al. 1987). We could only use Test 2 because of the short duration of the studies. Test 2 of the GSA and SISA data did not indicate lack of fit of the data (GSA: $\chi^2 = 0.008$, 1 df, $P = 0.93$; SISA: $\chi^2 = 0.702$, 1 df, $P = 0.40$). Test 2 was not

Figure 2.1. Location of Coconino (CSA), Gila (GSA), and Sky Islands (SISA) Mexican spotted owl population study areas in Arizona and New Mexico.

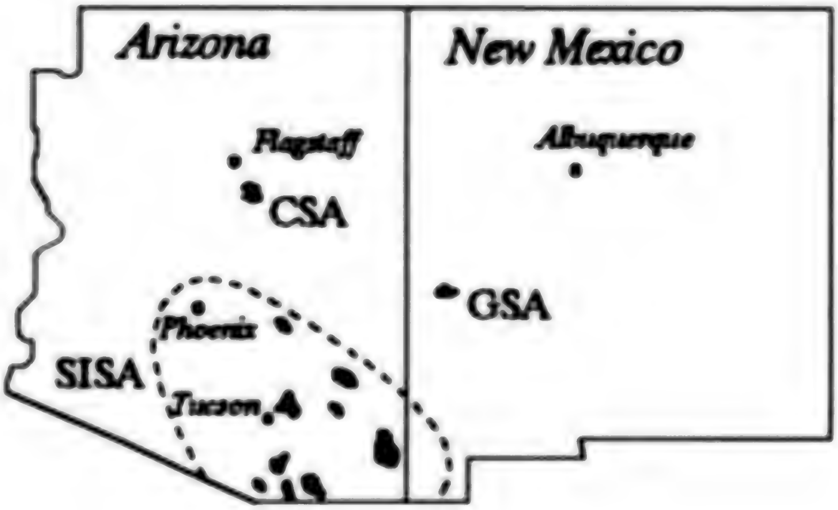

Table 2.1. Time periods and number of capture histories from three study areas used in estimating Mexican spotted owl survival.

	Coconino Study Area (CSA)	Gila Study Area (GSA)	Sky Island Study Area (SISA)
Age Class When Banded	1991-1993	1991-1993	1990-1993
Adults	41	52	55
Subadults	18	15	11
Juveniles	95	84	59

computable for the CSA because only one bird released in 1991 was not recaptured in 1992 but was captured in 1993.

For model selection, the GSA and CSA data sets were modeled together because they employed similar designs and methodologies (Gutiérrez et al. 1993, 1994), both occur in the Upper Gila Mountains RU, and we wanted to improve the precision of survival estimates by combining the data into one analysis. The procedures used allowed testing the assumption that survival and recapture rates were the same for these two study areas. The SISA data set was modeled separately from the CSA and GSA data sets because it was conducted by a separate set of investigators using somewhat different protocols, and because this study occurred in the Basin and Range - West RU. In modeling the GSA and CSA data, we considered the global model to be $\{\phi_{g*s*a}, p_{g*s*a}\}$ (AIC = 249.05, *K* = 28 parameters); it included study area (or group, *g*), sex (*s*), and age (*a*) effects. We did not include time effects because only two recapture periods were present in the data. The selected model $\{\phi_{J*g}, \phi_{S,A(GSA),S,AM(CSA)}, \phi_{AF(CSA)}, p_{S1}, p_{S2,A}\}$ (AIC = 223.24, *K* = 6) included (1) separate estimates of juvenile (*J*) survival for each study area, (2) a single estimate for subadults (*S*) and adults (*A*) of both sexes on the GSA combined with subadults of both sexes and male adults (*AM*) on the CSA, and (3) a single estimate for adult females (*AF*) on the CSA. No significant study area effects in terms of recapture probabilities (*p*) were found but there was an age effect (S1 ≠ S2 and A age classes). However, the estimate of $\hat{\phi}$ for CSA females was 1.000 ($\widehat{se}$ ($\hat{\phi}$) = 0.000), which was unsuitable for modeling purposes. Other than indicating that adult females may have higher survival than males, the $\hat{\phi}$ for adult females on the CSA was probably an artifact of limited number of capture occasions. Such a result is possible from a study with only three capture occasions. Therefore, we used the nearest model to the selected model; i.e., the model with the next lowest AIC. This model $\{\phi_{J*g}, \phi_{A,S}, p_{S1}, p_{A,S2}\}$ (AIC = 229.53, *K* = 5) included separate estimates of juvenile survival for the two study areas and a single estimate for subadults and adults, with no sex effects (Table 2.2). Recapture probabilities were modeled the same as the previous model.

Estimated differences in juvenile survival between the two study areas may represent differences in survey effort around the study areas and differences in study area size rather than real differences in the rates. For more explanatory details, refer to the Population Trends section.

We could not obtain reliable estimates from the SISA. For all the preliminary models examined, survival estimates became bounded at the upper limit of 1 indicating problems with the estimation procedure. The selected model (ϕ, *p*) had a single survival estimate ($\hat{\phi}$ = 1.0000, $\widehat{se}$ ($\hat{\phi}$) = 0.0000) and a single estimate of recapture probability ($\hat{p}$ = 0.2366, $\widehat{se}$ ($\hat{p}$) = 0.0344) with no age, sex, or time effects on either estimate. Such a conclusion is not biologically realistic; and given that the protocol used in this study did not stress resighting of marked birds (as evidenced by the low estimate of *p*), we do not feel these results are useful.

Table 2.2. Apparent survival (ϕ), recapture probability (*p*), and their sampling standard errors estimated for Mexican spotted owls between 1991 and 1993 on the Gila Study Area (GSA), New Mexico, and the Coconino Study Area (CSA), Arizona.

Age-class (Study area)	$\hat{\phi}$	$\widehat{se}$ ($\hat{\phi}$)	$\hat{p}$	$\widehat{se}$ ($\hat{p}$)
Juvenile (GSA)	0.0643	0.0366	0.7147[a]	0.1524
Juvenile (CSA)	0.2861	0.0785	0.7147[a]	0.1524
Subadult & Adult (GSA & CSA)	0.8889	0.0269	0.9818	0.0176

[a] Recapture probabilities for juveniles represent probability of recapture as an S1 or S2 individual.

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Binomial Survival Estimators from Radio-tracking Studies

Binomial estimators allow estimation of true survival (S) where $1 - S$ = mortality. Estimates of S can be derived from radio-telemetry data and are preferable to estimates of apparent survival when permanent emigration occurs, radios do not influence survival, and sufficient numbers of radios are available for precise estimates. We estimated annual survival for subadult and adult Mexican spotted owls based on 73 radio-marked individuals from six studies at four geographic locations (Table 2.3). We also used 22 juveniles from two independent studies, one in Colorado (R. Reynolds, unpub. data) and one in Utah (Willey 1992a, b). We selected the Kaplan-Meier product limit estimator (Kaplan and Meier 1958) as modified by Pollock et al. (1989) to analyze the radio-telemetry data. This estimator allowed for staggered entry of individuals during the sampling period and the use of right-censored data (exact fates of individuals unknown due to radio failure) without incurring the biases due to censoring discussed by White and Garrott (1990). In addition, this estimator is nonparametric and, therefore, does not require an underlying hazard function that must be mathematically tractable (Pollock et al. 1989).

Five important assumptions underlie the Kaplan-Meier estimator: (1) individuals have been randomly sampled; (2) survival of the marked animal is independent of other individuals; (3) attached radios do not influence survival; (4) censoring is random and unrelated to an individual's fate; and (5) newly marked individuals have the same survival rate as previously marked individuals. We were unable to test these assumptions because of low sample sizes and design of the studies. However, we felt that assumption (1) was probably not met because of the nature of the studies whereas assumptions (2)-(5) probably were met. However, controversy exists whether radios and their attachment (assumption 3) affect survival (Paton et al. 1991, Foster et al. 1992), although the studies reported here used tail-mounted radios rather than the backpacks discussed by the references. This assumption cannot be tested with just radio-tracking data.

Adult and subadult age classes were pooled for analyses because of the small sample of subadults in the radio-marked samples and for comparability with the mark-recapture estimates. Sex-specific estimates of adult and subadult survival were computed by pooling data across study areas. Pooling across study areas was necessary because of low sample sizes within each study area. In addition, data on both sexes from the Coconino National Forest were combined for comparison with the mark-recapture estimates from the CSA population study on that forest. The pooling of data across study areas and years prevented us from examining spatial and temporal variation in the Kaplan-Meier estimates of survival. In all Kaplan-Meier models, the annual sampling period started on 1 June because most birds were radio-marked just after this date, this coincided with approximately the middle of the sampling period for the population studies, and this was the "birth" date used for fledglings in population modeling (Franklin 1992). In all models, individuals tracked beyond the annual sampling period were recycled back to the beginning. For example, an individual that was radio-marked in July and then had radio failure in August of the following year would be initially added in July, added again in the following June, and then censored in August. In this way, the number of entries in the model exceeded the actual number of individuals tagged and the only fates for an individual were to die or be censored from the analysis.

Estimates of S for adults and subadults combined were close to identical for both sexes when study areas were pooled (Table 2.4). On the Coconino National Forest, Kaplan-Meier ($\hat{S}$) and mark-recapture ($\hat{\phi}$) estimates were compared for adult/subadult (both sexes combined) and juvenile age classes using a Wald test (Carroll and Ruppert 1988, Hosmer and Lemeshow 1989):

$$\chi^2 = \frac{(\hat{S} - \hat{\phi})^2}{\hat{\text{var}}(\hat{S}) + \hat{\text{var}}(\hat{\phi})}$$

Estimates from mark-recapture data were not significantly different from those estimated from the radio-telemetry data ($\chi^2 = 0.950$, 1 df, $P = 0.330$). Estimates for juvenile survival from

Table 2.3. Description of radio-telemetry studies conducted on adult and subadult Mexican spotted owls in the Upper Gila (Norther AZ, Coconino NF, AZ), Basin and Range - East (Lincoln NF, NM), Southern Rocky Mountains Colorado (Rocky Mts. CO), and Colorado Plateau (Zion NP, UT) RUs.

Study	Location	Time Period	Number of Individuals		
			Male	Female	Total
Ganey (1988)	Northern AZ	1986-1987	5	3	8
Ganey and Block (unpublished data)	Coconino NF, AZ	1990-1993	7	6	13
Kroel and Zwank (1991)	Lincoln NF, NM	1990-1991	4	5	9
Ganey and Block (unpublished data)	Lincoln NF, NM	1992-1993	9	6	15
Reynolds (unpublished data)	Rocky Mts., CO	1992-1993	9	4	13
Willey (unpublished data)	Zion NP, UT	1991-1992	9	3	12
		Total	43	30	73

the radio-telemetry data (Table 2.4) were not significantly different from estimates from mark-recapture data collected on the CSA ($\chi^2 = 0.752$, 1 df, $P = 0.386$) or the GSA ($\chi^2 = 2.749$, 1 df, $P = 0.097$).

Survival Estimators from FS Region 3 Monitoring Studies

The FS has inventoried Mexican spotted owl MTs since 1984, and conducted informal and formal monitoring since 1989 (Table 2.5). Summaries of monitoring data were supplied by the FS (see Sources of Information section). For each MT, presence of owls (single male, single female, single unknown, unknown age and sex, or pair, or else unchecked) and result of reproduction (0, 1, 2, 3 young, unchecked, or unconfirmed) were noted.

Persistence of a pair can be estimated from occupancy data gathered during the FS spotted owl monitoring program. Pair persistence rate is defined here as the probability that a territory containing a pair of owls in one year will contain a pair in the succeeding year (but see discussion of biases below). An individual territory must be monitored both years to compute this statistic. The overall persistence rate was 80.5% for 824 territories monitored with formal and informal protocols (Table 2.6). Note that some territories had persistence estimates for their first year because some of these MTs were surveyed as part of inventory the preceding year. No differences in the persistence rate across years were detected for the informal monitoring data (1989-1993; $\chi^2 = 2.543$, 4 df, $P = 0.637$), or the formal monitoring data (1989-1993; $\chi^2 = 3.233$, 4 df, $P = 0.520$). We found no significant differences for year ($\chi^2 = 4.2546$, 4 df, $P = 0.373$), monitoring type ($\chi^2 = 0.7133$, 1 df, $P = 0.398$), or their interaction ($\chi^2 = 1.3162$, 4 df, $P = 0.859$) using a logistic regression model (Hosmer and Lemeshow 1989).

The overall persistence rate based on pairs versus no pairs from 1989-1993 formal and informal monitoring types (0.805, SE = 0.0138) was used to estimate adult survival (S_a). If pairs are assumed to remain on the same territory, lack of a pair on a territory that was previously occupied infers the death of one or both members of the pair. This is a difficult assumption to accept because pairs have been observed to change nest locations, but it allows some inference about adult survival. The dichotomy of pairs versus no pairs was used because this assumption is the simplest one possible for estimating survival from persistence. Single birds (i.e., persistence of a single) could be included in the analysis to estimate survival, but would require an assumption that single males persisted on the territory at the same rate as single females. Another bias is failure to detect a pair when both birds are present. Using the dichotomy of pairs versus no pairs, and assuming

Table 2.4. Estimates of true survival (S) for Mexican spotted owls based on radio-telemetry data.

Group	n^a	$\hat{S}$	$\widehat{se}(\hat{S})$	95% C.I.
ADULTS				
All Study Areas				
Males	71	0.799	0.062	0.676 - 0.970
Females	47	0.806	0.084	0.642 - 0.970
Coconino N.F.				
Both Sexes	41	0.800	0.087	0.630 - 0.970
JUVENILES				
Colorado & Utah	25	0.124	0.058	0.010 - 0.238

[a] Number of entries in Kaplan-Meier estimator

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Table 2.5. Number of management territories checked one or more times during the Mexican spotted owl monitoring program of FS Region 3.

Year	Formal	Informal	Inventory
1984	0	0	13
1985	0	0	37
1986	0	0	17
1987	0	0	28
1988	0	0	129
1989	90	56	153
1990	40	221	199
1991	150	233	75
1992	157	287	49
1993	159	225	44

Table 2.6. Persistence of a Mexican spotted owl pair on a territory for formal and informal monitoring data, with "persistence" defined as the probability a pair of owls will exist on a territory given that a pair was on the same territory the previous year. Data are from the monitoring program of FS Region 3.

	Formal		Informal	
Year	*n*	Persistence	*n*	Persistence
1989	49	0.796	14	0.857
1990	23	0.783	109	0.743
1991	97	0.804	99	0.758
1992	97	0.876	114	0.816
1993	111	0.856	111	0.784

that both adults survive at the same rate and independent of one another, then $(\hat{S}_a)^2 = 0.805$, or $\hat{S}_a = 0.897$ ($\hat{se}(\hat{S}_a) = 0.0077$). This estimate is very close to the observed estimate of apparent survival from the population studies (0.889).

Two biases of opposite direction are possible for an estimate of adult survival based on pair persistence. A pair of owls may leave a territory for reasons other than the death of one member of the pair, resulting in an estimate of survival biased low. In contrast, one member of a pair may die, but the remaining member may be able to obtain another mate and stay on the territory. Another possibility is that both members of a pair die, but the territory is occupied by a new pair. In these situations, the estimate of survival is biased high. For this reason, we note the similarity of persistence-based survival $(\hat{S}_a)$ to mark-recapture estimates $(\hat{\phi})$ but we relied solely on the mark-recapture estimates to estimate population trends.

The 1989-1993 formal and informal persistence data were also analyzed by recovery unit (Table 2.7) using a logistic regression model that included year (1989-93), recovery unit and the interaction between the two factors. No differences were found for year ($\chi^2 = 5.9688$, 4 df, $P = 0.202$), recovery unit ($\chi^2 = 2.6129$, 4 df, $P = 0.624$), or the interaction between the two ($\chi^2 = 13.1995$, 15 df, $P = 0.587$). Therefore, a reduced model with only recovery unit was analyzed; and again, no differences were found for recovery unit ($\chi^2 = 7.0271$, 4 df, $P = 0.134$).

Survival Estimates from Band Return Data

Records from the FWS Banding Laboratory were checked to determine if adequate banding data were available for estimation of survival. All records obtained from the Laboratory were part of studies reported above, so did not provide additional information.

Age- and Sex-specific Fecundity

Fecundity (m_x) can be defined as the mean annual number of live births of a given sex by a parent of that same sex over an interval of age (Caughley 1977), e.g., the number of female young per adult female. For Mexican spotted owls, we defined live births as the number of young fledging from the nest because the number of live births at hatching was not measured. To estimate fecundity, we initially used the number of total young (e.g. of both sexes) fledged per pair as the response variable from the

Table 2.7. Persistence of a pair of Mexican spotted owls on a territory for the five recovery units contained in the FS Region 3 monitoring database for 1989-1993, with "persistence" defined as the probability a pair of owls will exist on a territory given that a pair was on the same territory the previous year. Survival rate is the probability that both members of the pair survived the year, and is the square root of persistence.

Recovery Unit	*n*	Persistence	Survival Rate
Basin and Range - East	258	0.779	0.883
Basin and Range - West	114	0.833	0.913
Colorado Plateau	8	0.500	0.707
S. Rocky Mountains - NM	31	0.742	0.861
Upper Gila Mountains	413	0.823	0.823

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two appropriate population studies (GSA and CSA) and the FS monitoring database. The third population study (SISA) was included in the analysis of the FS monitoring database because the methods used and territories monitored were identical. We analyzed the two population studies separately from the monitoring database to obtain fecundity estimates directly related to the mark-recapture estimates of survival. Estimates for number of young fledged were converted into fecundities by dividing the means in half and adjusting the standard errors accordingly. This procedure assumed a 1:1 sex ratio at fledging and that sites where reproductive data were gathered were independent across years.

Fecundity Estimates from Population Studies

We used the general linear models procedure in SAS (PROC GLM: SAS Institute Inc. 1985) to examine differences in time, age, and study areas for number of young fledged by male and female Mexican spotted owls. Average number of young fledged for all years differed between the GSA and CSA ($F = 3.73$; 1, 151 df; $P = 0.055$) but average number of young per year for combined study areas did not differ among years of study ($F = 1.58$; 2, 151 df; $P = 0.210$). Based on *a priori* linear contrasts, number of young fledged by first-year subadults was different from second-year subadults and adults combined for both males ($F = 3.45$; 1, 151 df; $P = 0.065$) and females ($F = 16.24$; 1, 151 df; $P < 0.001$; Table 2.8).

Fecundity Estimates from FS Region 3 Monitoring Database

An objective of the FS Region 3 monitoring program was to monitor reproduction (Table 2.9). Differences in mean reproduction across monitoring methods and years were tested with analysis of variance (ANOVA). Reproduction is a categorical variable, because only values of 0, 1, 2, and 3 young are observed. However, ANOVA techniques are still appropriate because of the large sample sizes involved (even though sample sizes are unequal); and hence, the cell means being approximately normally distributed as a result. Another possible procedure might be a log-linear analysis. However, the null hypothesis of a log-linear model would be that the distributions are the same, compared to the null hypothesis of ANOVA that the means are the same. Thus, a log-linear analysis may reject the null hypothesis even when the mean fecundity rates do not differ. We did not use a log-linear analysis here because we are primarily interested in the mean rates.

All data for 1989-1993 were used to test for differences between formal and informal monitoring types (Table 2.9). The year effect was significant ($F = 14.09$; 4, 685 df; $P < 0.001$), but monitoring method ($F < 0.001$; 1, 685 df; $P = 0.956$) and the interaction ($F = 1.23$; 4, 685 df; $P = 0.295$) were not significant. The average number of young fledged/pair across years was 1.006 ($n = 695$, SE = 0.037), giving a fecundity estimate of 0.503 (SE = 0.018).

Differences in mean reproduction among recovery units with years included in the model was tested for formal and informal monitoring data for 1989-1993. The year effect was significant ($F = 3.03$; 4, 672 df; $P = 0.017$), as were recovery unit ($F = 12.55$; 4, 672 df; $P < 0.001$), and their interaction ($F = 2.86$; 14, 672 df; $P < 0.001$). Mean reproductive rates are given in Table 2.10 for each year and recovery unit, plus the recovery unit mean across the years 1989-1993. Reproduction estimates from the FS monitoring database were compared to estimates from the population studies (CSA and GSA) for the same two National Forests, i.e., Coconino and Gila. The ANOVA model included year (1991-1993), National Forest (Coconino, Gila), and monitoring method (population study versus formal and informal monitoring), plus all the interactions of these three factors. None of the factors was significant ($P \geq 0.300$) except the interaction between forest and monitoring method ($F = 5.24$; 1, 267 df; $P = 0.023$). Table 2.11 presents the four means that produced this interaction.

Although the reasons behind this interaction are unknown, we speculate that two explanations are possible for this difference. First, differences in following the monitoring protocols between personnel in the Coconino and Gila National Forests may have led to the

Table 2.8. Sample size (*n*) and estimates (mean and SE) of number of young fledged/pair and fecundity (female young fledged/female) from the GSA[a] and CSA[a] Study Areas, 1991-1993.

		No. Young Fledged/Pair		Fecundity	
	n[b]	**Mean**	**SE**	$\hat{m}$[c]	$\hat{se}(\hat{m})$[d]
GSA					
Female S2 & A	68	1.1617	0.1060	0.5809	0.0530
S1	7	0.0000	0.0000	0.0000	0.0000
Male S2 & A	75	1.0533	0.1038	0.5267	0.0519
S1	0	--------	--------	--------	--------
CSA					
Female S2 & A	74	1.5405	0.1250	0.7703	0.0625
S1	8	0.2500	0.2500	0.1250	0.1250
Male S2 & A	73	1.5205	0.1266	0.7603	0.0633
S1	9	0.5556	0.3379	0.2778	0.1684

[a] Coconino study area (CSA), Gila study area (GSA)

[b] Number of pairs adequately checked for reproductive activity

[c] $\hat{m}$ = (mean number young fledged/pair)/2, i.e. an equal sex ratio at fledging is assumed

[d] $\hat{se}(\hat{m})$ = SE/2

Table 2.9. Number of Mexican spotted owl pairs checked (*n*), mean, and standard error (SE) for number of young fledged per pair for 1989-1993, based on formal and informal monitoring methods.

Year	Formal			Informal		
	n	Mean	SE	*n*	Mean	SE
1989	61	1.246	0.116	18	0.944	0.206
1990	20	0.200	0.092	77	0.494	0.092
1991	79	1.177	0.106	81	1.321	0.112
1992	99	1.172	0.097	105	1.152	0.095
1993	85	0.882	0.105	70	0.743	0.101

observed differences between the population studies and other monitoring systems. Monitoring approaches in the population studies are the same because each was conducted by the same research group using standardized methods and experienced personnel. A second possibility is that the population study areas are not representative of the surrounding habitat for their respective forests; and thus, the observed difference is real and caused by habitat differences on each forest. Alternatively, monitoring sites may not be representative of the forest because management territories were selected because of proposed timber sales (with better quality owl habitat) or historical locations (with easy access).

Effects of Forest Type on Life History Traits

We examined the effects of forest type on both reproduction and persistence, which can be viewed as an indirect measure of survival. We used two sources of information to examine the effects of forest type on reproduction: the FS Region 3 monitoring database and data from Skaggs and Raitt (1988). For persistence, we used data from the FS Southwestern Region monitoring database. These were the only sources of data available to the Team which coupled habitat information with data used to estimate life history traits.

Effects on Reproduction

The FS Region 3 monitoring database included for each MT the percent (recorded to the nearest 25%) of the core area consisting of the following forest types: mixed conifer, pine-oak, ponderosa pine, pinyon-juniper, oak, Arizona cypress, sycamore, other riparian, and unsuitable for owls. We computed the Pearson correlations (r) between each of these forest type variables and number of young produced on an MT for each year, given that a pair of owls was present. Significant correlations were found for mixed-conifer ($r = -0.131$, $P < 0.001$), pine-oak $r = 0.084$, $P = 0.011$), other riparian ($r = 0.062$, $P = 0.064$), and unsuitable ($r = 0.098$, $P = 0.003$), with none of the remaining variables significant ($P > 0.154$). This analysis suggested that the more mixed-conifer present, the lower the reproductive rate (a negative correlation), and the more unsuitable forest type, the greater the reproductive rate (a positive correlation). When the forest type variables were used in a step-wise regression to predict number of young fledged, mixed-conifer and unsuitable were both selected ($P \leq 0.017$), while none of the remaining variables was included ($P > 0.150$). The regression explained only a very small amount (2.3%) of the variation in the number of young fledged, with the signs of both variables in the opposite direction of what we expected based on radio-telemetry studies ([illegible]aney and Dick 1995).

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Table 2.10. Number of Mexican spotted owl pairs checked (*n*), mean, and standard error (SE) for number of young produced per pair for 1989-1993 by recovery unit, based on formal and informal monitoring methods.

Recovery Unit	Year	*n*	Mean	SE
Basin and Range - East	1989	56	1.161	0.124
	1990	47	0.021	0.021
	1991	53	1.264	0.140
	1992	60	0.717	0.107
	1993	45	0.356	0.111
	All	261	0.736	0.057
Basin and Range - West	1989	0	---	---
	1990	7	0.143	0.143
	1991	25	0.960	0.204
	1992	32	1.469	0.162
	1993	16	1.250	0.233
	All	80	1.150	0.110
Colorado Plateau	1989	0	---	---
	1990	1	2.000	---
	1991	1	2.000	---
	1992	2	2.000	0.000
	1993	2	3.000	0.000
	All	6	2.333	0.211
S. Rocky Mountains - NM	1989	5	0.800	0.490
	1990	5	0.000	0.000
	1991	5	1.400	0.600
	1992	10	1.300	0.335
	1993	6	0.167	0.167
	All	31	0.806	0.188
Upper Gila Mountains	1989	18	1.333	0.181
	1990	37	1.027	0.142
	1991	76	1.316	0.105
	1992	100	1.300	0.099
	1993	86	0.977	0.094
	All	317	1.186	0.052

Table 2.11. Sample size (*n*), mean, and standard error (SE) for the number of Mexican spotted owl young produced per territory for 1991-1993, based on population studies (CSA and GSA[a]) and formal and informal monitoring methods in the Coconino and Gila National Forests.

	Population Study			Formal & Informal Monitoring		
National Forest	***n***	**Mean**	**SE**	***n***	**Mean**	**SE**
Coconino	82	1.415	0.123	88	1.045	0.098
Gila	75	1.053	0.104	34	1.294	0.137

[a] Coconino study area (CSA), Gila study area (GSA).

When we examined the database to determine the distribution of territories with mixed-conifer, we found that 276 territories with 100% mixed-conifer cover occurred in the Basin and Range - East RU. These 276 territories were 79.3% of the territories that had 100% mixed-conifer. However, only 6 territories with <100% mixed-conifer occurred in the Basin and Range - East, or 1.1% of <100% mixed-conifer. Because of this inequitable distribution of mixed-conifer territories across recovery units, the comparison of mixed-conifer becomes a comparison of recovery units, not forest type, with nearly total confounding of recovery unit and mixed-conifer habitat. As shown in Table 2.10, the Basin and Range - East RU has lower fecundity than all the other recovery units. When the recovery unit is included in the step-wise regression, the Basin and Range - East unit is included in the regression, but the mixed-conifer variable is excluded. Possibly, mixed-conifer may be the underlying cause of the differences between recovery units. However, so many other factors, such as climate, are confounded with this variable that such an inference is highly questionable.

A similar problem occurs with the unsuitable forest type variable. Only 9 of the 907 territories contained unsuitable forest type and all 9 occur in the Tonto NF in the Upper Gila Mountains RU. Why these 9 territories had better than average fecundity is not clear, but the unbalanced distribution of the unsuitable forest type across territories implies that the conclusion that the unsuitable forest type increases fecundity is inappropriate.

Because comparisons of forest type within territories are confounded with recovery unit, the FS Southwestern Region monitoring database is unsuitable to make such comparisons. To test for the effect of forest type on fecundity, a sample that is not confounded must be taken (such as the Skaggs and Raitt data discussed next), where the differences between territories is just the forest type, and these differences are not confounded by differences in climate, etc. Other problems are inherent in this approach. The spatial scale at the territory level may not be the scale at which owls perform habitat selection. Overall forest configuration may not be as important as specific habitat characteristics within the territory, such as a nest tree or roost sites needed by the nesting pair. Management territory boundaries are assigned subjectively by biologists, and not based on empirical data delimiting areas actually used by owls. Hence, the percentages of the various habitats included in the territory reflects the biologist's perception, not what owls may actually be using. Further, unless habitat is manipulated, cause and effect cannot be inferred from the kind of analysis performed here, even though it is tempting to do so.

We reanalyzed data presented in Skaggs and Raitt (1988), who surveyed 18 quadrats, each 23 km^2 (9 mi^2) in size. Six quadrats were placed randomly into three areas, each of which was dominated by either pinyon-juniper (PJ), ponderosa pine (PP), or mixed-conifer (MC) forest types. We used a *t*-test to test whether the number of young fledged per pair was different between PP and MC forest types using quadrats as replicates. We did not include the PJ forest type in the analysis because no pairs were found in the quadrats dominated by this type. We found no significant difference in the number of young fledged per pair ($t = 1.58$; 8 df; $P = 0.152$) although numbers of owls differed by forest type (Ward et al. 1995), suggesting that demographic processes may differ between the forest types. The estimate for MC forest types ($\bar{x} = 0.88$ fledged young per pair, SE = 0.281) was greater than the PP type ($\bar{x} = 0.25$, SE = 0.25). Lack of significance may have been due to low power resulting from small sample sizes, thus we feel the study should be repeated with larger numbers of quadrats.

Effects on Persistence

Logistic regression models predicting persistence from the forest type variables were also constructed. Only mixed-conifer ($\beta = -0.0047$, $P = 0.076$), ponderosa pine ($\beta = 0.0072$, $P = 0.090$), and oak ($\beta = 0.0346$, $P = 0.003$) appeared important in predicting persistence, with the remainder of the habitat variables not significant ($P > 0.167$). As with reproduction, the model for mixed-conifer suggests that increasing amounts of this forest type in the defined core area of MTs results in decreasing persistence, and ultimately fitness. As discussed previously for the fecundity analysis, the inequitable distribution of mixed conifer habitat across recovery units makes this analysis inappropriate.

Conclusions

Environmental conditions may greatly affect reproduction and/or survival of nestlings through fledging and to adulthood. However, adult survival rates appear to be relatively constant across years, as suggested by high pair persistence rates. Such life history characteristics are common for K-selected species, for which populations remain relatively stable even though recruitment rates might be highly variable. With no recruitment, the population only declines at the rate of 1 minus adult survival, or the adult mortality rate.

Undoubtedly, long-lived organisms experience a range of environmental conditions through time. Conditions that result in simultaneously low survival and reproduction can lower average population persistence rates dramatically, when examined over a period that is short relative to the organism's life span. The converse, simultaneously high survival and reproduction, that would raise the expected population persistence dramatically, is also possible. However, the magnitude of the effect of such a sudden decrease or increase on average persistence will naturally decline as the observation of a given population is extended in time, while the probability of detecting such events will increase with observation time. In addition, dispersal among subpopulations can greatly influence the persistence of relatively isolated populations (Keitt et al. 1995). Successful dispersal may also be a rare and time-dependent event or a density-dependent event. We currently have little information on the frequency of immigration and its associated influence on population persistence. Thus, reliable conclusions on the persistence of Mexican spotted owl populations must await additional study. Without reliable projections on the owl's persistence, we can only summarize conclusions about the owl's survival and reproduction based on short-term but current knowledge.

Survival

Annual survival rates of adult Mexican spotted owls is ~0.8-0.9 based on short-term population and radio-tracking studies and longer-term monitoring studies. These annual survival estimates can be viewed as the probability of an individual surviving from one year to the next or as the proportion of individuals that will survive from one year to the next. A variety of different estimators of adult survival using different types and sets of data gave similar results. Juvenile survival is considerably lower (~0.06-0.29) than adult survival. Juvenile survival also appears more variable spatially, although this conclusion reflects only two population study areas and two radio-telemetry studies spanning two years or less.

We strongly suspect that estimates of juvenile survival from the population studies are biased low because of (1) a high likelihood of permanent dispersal (emigration) from the study area, especially the smaller GSA, and (2) a lag of several years before marked juveniles reappear as territory holders, at which point they are first detected for recapture. Concerning the first point, juvenile northern spotted owls have a high dispersal capability (reviewed in Thomas et al. 1990). If Mexican spotted owl juveniles have a similar dispersal capability, we expect that a substantial portion of marked juveniles will emigrate from the respective study areas. However, estimates from the radio-telemetry study roughly corroborated the low estimates from the population studies. Biases in the radio-telemetry estimates of juvenile survival can result if radios significantly affect their survival. Whether radios or their attachment affect survival of northern spotted owls is debatable (Paton et al. 1991, Foster et al. 1992). Concerning the second point, Franklin (1992) found a lag of 1-4 years between the time when juvenile northern spotted owls were banded and subsequently recaptured. If this process is similar for Mexican spotted owls, then the current population studies may be of insufficient duration to adequately estimate juvenile survival.

In summary, our survival estimates are based primarily on studies of insufficient duration or studies not explicitly designed to estimate survival. In most cases, the data were too limited to support or test the assumptions of the estimators used. However, the age- and sex-specific estimates of survival calculated here are useful at this point as qualitative descriptors of the life-history characteristics of Mexican spotted owls. That is, Mexican spotted owls exhibit high adult and relatively low juvenile survival. In this respect, Mexican spotted owl survival probabilities appear similar to northern (see review in Burnham et al. 1994) and California spotted owls (Noon and McKelvey 1992).

Reproduction

Reproductive output of Mexican spotted owls, defined as the number of young fledged per pair, varies both spatially and temporally. Mexican spotted owls may have a higher average reproductive rate (1.001 fledged young per pair) than the California (~0.712; Noon and McKelvey 1992) and the northern spotted owl (~0.715; Thomas et al. 1990). Both of the other subspecies exhibit temporal fluctuations in reproduction similar to the Mexican subspecies.

Effects of Forest Type

We feel the data collected by Skaggs and Raitt (1988) were more appropriate for examining the effects of forest type on reproduction than our analysis of the monitoring data. Their study was designed to look at the relationship between forest type, density and reproduction whereas the monitoring program was not. However, the Skaggs and Raitt data lacked sufficient statistical power to detect differences in reproductive output between the three forest types. This problem arose primarily because significantly fewer spotted owls were found in the pinyon-juniper and pine forest types than in mixed-conifer forests (Ward et al. 1995). The primary problem in using data on forest types from MTs is that the data are confounded for making the desired comparisons. Further, the core delineations were subjective. In addition, forest types included within MT boundaries may not have been used by the owls for which the given MT was established. For these reasons, we feel that definitive data linking Mexican spotted owl reproduction and forest type are still lacking, even at the coarse-grained scale that we examined. Further, forest type affects more than just reproduction; so additional data are needed to evaluate how forest type affects survival, and ultimately fitness.

POPULATION TRENDS

We estimated trends in Mexican spotted owl populations two ways: as the finite rate of population change, lambda (λ), and as trends in the rate of occupancy of spotted owl territories.

Finite Rate of Population Change

Lambda was computed for female Mexican spotted owls from the age-specific survival and fecundity rates obtained from two population study areas, the GSA and CSA (see Life History Parameters section). Lambda is a useful metric because it measures both the direction and magnitude of change in population trends. Direction of population trends can be characterized as stationary ($\lambda = 1$), declining ($\lambda < 1$) or increasing ($\lambda > 1$). The magnitude in change is expressed as the annual rate of change, R, where $R = \lambda - 1$ for a birth-pulse population. From a population management perspective, the statistical hypothesis is $\lambda < 1$ versus the null hypothesis that the population is either stationary or increasing ($\lambda \geq 1$). This is a one-sided test of the form:

$$Z = \frac{1 - \hat{\lambda}}{se(\hat{\lambda})},$$

where Z is normally distributed with $\mu = 0$, $\sigma^2 = 1$.

We used a Leslie matrix (Leslie 1945) as modified by Usher (1972) to compute estimates of λ based solely on the estimates of age-specific fecundity and survival probabilities obtained from the two study areas. The form of the matrix followed Usher (1972):

$$\begin{bmatrix} \phi_0 m_1 & \phi_1 m_1 \\ \phi_0 & \phi_1 \end{bmatrix},$$

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where ϕ_0 = juvenile survival, ϕ_1 = survival for the subadult and adult age classes combined, m_1 = S1 fecundity, and m_2 = fecundity for S2 and adult age classes combined. The form of the matrix assumed a birth-pulse population with a post-breeding census and a projection interval of one year (Noon and Sauer 1992). Lambda was estimated as the dominant eigenvalue associated with the right eigenvector derived from the matrix using power analysis (Caswell 1989). The se(λ) was estimated using the delta method (Seber 1982, Alvarez-Buylla and Slatkin 1994), which included the sampling covariances for the estimated survival probabilities.

Parameter estimates used to compute λ (Table 2.12) were taken from only the two population studies because all of the required parameters were estimated from data within the same spatial and temporal scales. Survival estimates were based on the mark-recapture estimators. Estimates of λ were computed separately for the two studies because of significant differences in fecundity and juvenile survival between the two areas.

We obtained estimates of λ which were significantly lower than 1 for the GSA but were not significantly different from 1 for the CSA (Table 2.13). These estimates of λ represent trends in populations for only the places and times of study, and are based on only 3 years of data collection. We believe the estimate of λ from GSA is <1 because of bias in the estimate of ϕ_j due to emigration from the study area. GSA is about 1/2 the size of CSA, so that the bias of juvenile emigration is greater for this smaller study area. The bias of ϕ_j from juvenile emigration from the study area is a function of study area size. E. Forsman (FS, Pacific Northwest Forest and Range Experiment Station, Olympia, WA, pers. comm.) found juvenile emigration rates for northern spotted owls of ~60% using radio tracking.

We also estimated the parameter values necessary to obtain a value for λ of 1, or a stationary population, given that the other parameter estimates were the same and were unbiased and precise (Table 2.14). These results suggest that estimate of juvenile survival for the GSA must increase substantially (i.e., remove the bias in the estimate from emigration from the study area) for the population to be stationary. However, the estimate of juvenile survival for the CSA was close to that expected for a stationary population on the GSA. The difference in juvenile survival between the two areas may be attributed to 2 causes. First, survey effort may differ between the 2 study areas. FS personnel conduct more Mexican spotted owl surveys in the area surrounding the CSA than around the GSA and hence more color-banded juveniles are reported (M. Seamans, Humboldt State Univ., Arcata, CA, pers. comm.). Second, as discussed above, the CSA is almost twice as large as the GSA, so that juveniles may be less likely to disperse off the CSA.

The large value for S1 fecundity (given that $\lambda = 1$) for the GSA results from λ being insensitive to that parameter, so that a biologically unreasonable value is needed to obtain $\lambda = 1$. That is, the change needed in S1 fecundity to make $\lambda = 1$ must be so large that the value is biologically impossible.

Occupancy Rate as Measure of Population Change

From the monitoring database summarized by the FS, we evaluated the occupancy rate of territories, expressed as the percent of territories occupied by owls, as a measure of trends in the Mexican spotted owl population. For the formal and informal monitoring data (Table 2.15), the overall occupancy rate of territories was 63.8% pairs, 15.0% not detected (absent), and 21.2% with a single bird, or presence of a bird or birds. The presence of just a single bird or no detections may result from inexperienced crews performing the surveys, and hence a biased estimate of the actual number of pairs. A logistic regression model of pair versus no pair according to year (1989-1993), monitoring type (informal and formal), and the interaction of these two variables suggests a significant difference in occupancy rate for monitoring type ($\chi^2 = 3.1840$, 1 df, $P = 0.074$), but no differences in the other terms ($P > 0.288$). Presumably, the best quality territories were incorporated into the formal monitoring system with a pair occupancy rate of 67.6% versus 61.0% for

Table 2.12. Parameters used to estimate λ for Mexican spotted owls on the GSA[a] and CSA study areas.

Study Area	Parameter (θ)	$\hat{\theta}$	$\hat{\theta}$ $\widehat{se}$
GSA	Juvenile Survival	0.0643	0.0366
	Subadult/ Adult Survival	0.8889	0.0269
	S1 Fecundity(♀)	0.0000	0.0000
	S2/Adult Fecundity(♀)	0.5809	0.0530
	cov(ϕ_0, ϕ_1)	-0.0001	---------
CSA	Juvenile Survival	0.2861	0.0785
	Subadult/ Adult Survival	0.8889	0.0269
	S1 Fecundity(♀)	0.1250	0.1250
	S2/Adult Fecundity(♀)	0.7703	0.0625
	cov(ϕ_0, ϕ_1)	-0.0008	---------

[a] Coconino study area (CSA), Gila study area (GSA).

Table 2.13. Estimates and standard errors of λ for female Mexican spotted owls on the CSA[a] and GSA[a] study areas. The Z statistic and probability level are for a one-sided test of the null hypothesis of $\lambda < 1$ versus the alternative hypothesis $\lambda \geq 1$.

Study Area	$\hat{\lambda}$	$\widehat{se}(\hat{\lambda})$	Z	P
GSA	0.9247	0.0318	-2.367	0.009
CSA	1.077	0.0453	1.700	0.955

[a] Coconino study area (CSA), Gila study ar

Table 2.14. Estimates of population parameters for Mexican spotted owls on the GSA[a] and CSA[a] study areas, and the value of the parameter that gives $\lambda = 1$, provided that all other parameters remain at their original estimate.

Study Area	Parameter (θ)	$\hat{\theta}$	$\hat{\theta}_{\lambda=1}$
GSA	Juvenile Survival	0.0643	0.2152
	Subadult/ Adult Survival	0.8889	0.9640
	S1 Fecundity	0.0000	10.9286
	S2/Adult Fecundity	0.5809	1.9468
CSA	Juvenile Survival	0.2861	0.1590
	Subadult/ Adult Survival	0.8889	0.8140
	S1 Fecundity	0.1250	0.0000
	S2/Adult Fecundity	0.7703	0.4212

[a] Coconino study area (CSA), Gila study area (GSA)

informal monitoring; and hence, formal monitored territories were more likely to be occupied. However, the formal monitoring system looks more intensively at the sites for owls, so this difference in occupancy rate may be because of search procedures, which we suggest as the most likely scenario.

We examined differences in occupancy rate (Table 2.15) with a logistic regression model that included recovery unit, monitoring type (informal and formal), and the interaction of these two variables for the years 1989-1993. Type of monitoring was not significant ($\chi^2 = 0.0191$, 1 df, $P = 0.890$), but recovery unit ($\chi^2 = 22.7979$, 4 df, $P < 0.001$) and the interaction of recovery unit and type of monitoring ($\chi^2 = 16.1657$, 4 df, $P = 0.003$) were significant.

As defined and used here, occupancy rate is a rather artificial parameter because the selection of territories for inclusion in the monitoring database depends on judgement of human observers. MT boundaries are set subjectively, so they do not necessarily represent owl home ranges. Further, MTs may encompass more than one pair (May et al. in press), although this possibility is not supposed to occur. Changes in occupancy rate probably correspond more with the addition of new MTs to the list of those already monitored by the FS, level of effort used to monitor the MTs (i.e., number of MTs monitored that meet formal monitoring protocols), and other administrative factors rather than true change in the owl population. As a complicating factor, MTs are not a random sample of all existing Mexican spotted owl territories. As can be inferred from Figure 2.2, the percent of MTs occupied has dropped since 1989 because all new MTs added to the monitoring system are initially occupied. Habitat changes induced by forest alterations over the next several decades will make some of the currently occupied MTs unsuitable. Thus, we expect that occupancy rate will decline for existing territories. New MTs will probably be added to compensate for loss of existing territories, so change in occupancy rate does not provide a valid inference about changes in the owl population.

Conclusions

We have little confidence in our estimates of population trends for the following reasons. First, accurate and precise estimates of λ depend on the accuracy and precision of the parameter estimates used in the calculations. Estimates of juvenile survival may be biased low for reasons stated previously and the time over which parameters have been estimated is insufficient.

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Table 2.15. Number of Mexican spotted owl territories checked (*n*) and the percent of them occupied by a pair of owls for 1989-1993, based on formal and informal monitoring methods.

	Formal		Informal	
Recovery Unit	*n*	Occupancy Rate (%)	*n*	Occupancy Rate (%)
Basin and Range - East	185	70.8	222	60.8
Basin and Range - West	73	82.2	84	71.4
Colorado Plateau	12	41.7	9	22.2
S. Rocky Mountains - NM	30	43.3	26	84.6
Upper Gila Mountains	259	74.9	400	71.5

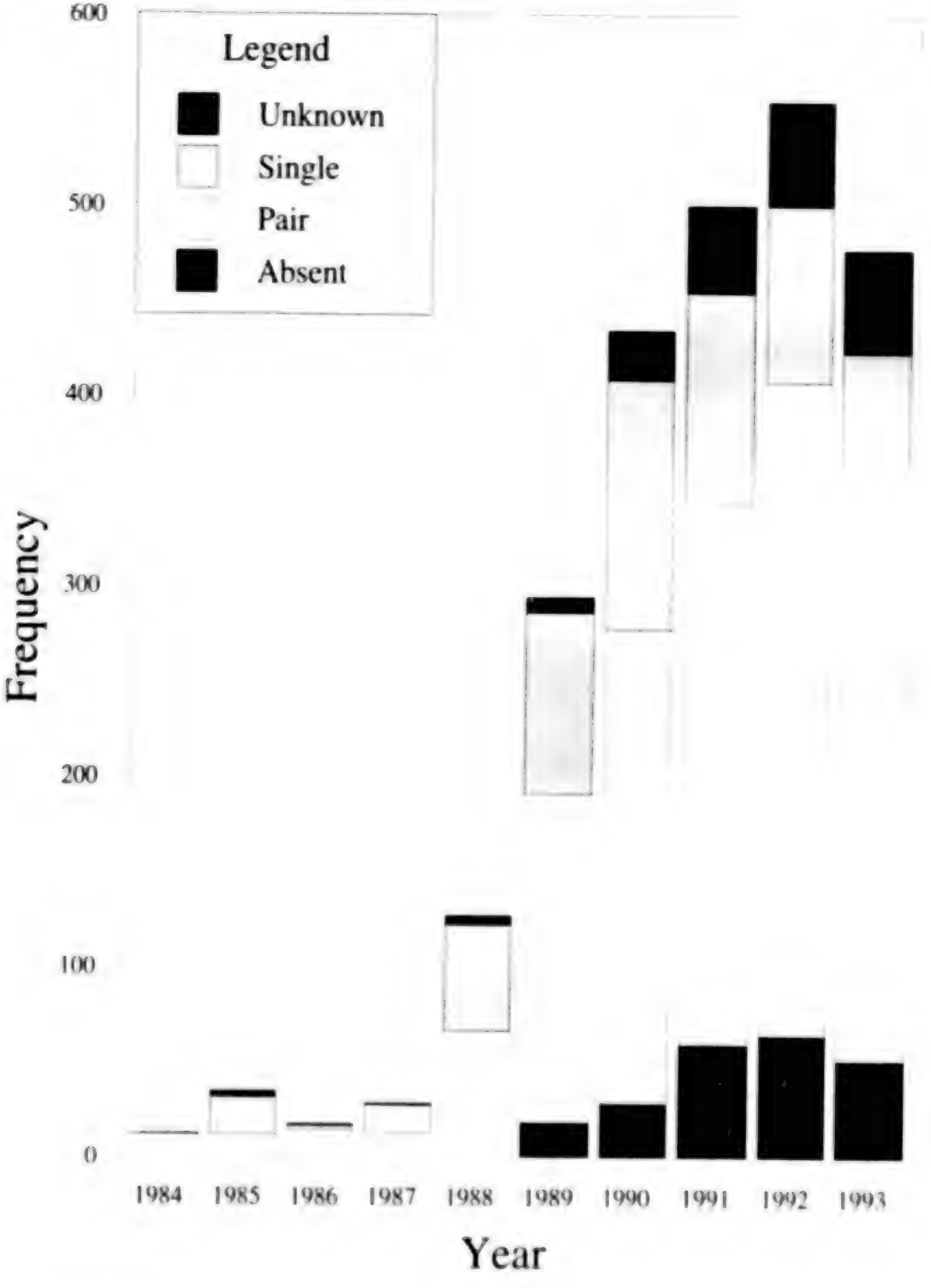
Second, the population studies from which parameter estimates were derived have not been conducted for a sufficiently long period to capture temporal variation. If one considers λ as an average rate of change over the study period, then three years is insufficient to adequately estimate λ from both biological and statistical perspectives. Third, rates of change estimated through occupancy provide little information on how Mexican spotted owl populations are changing for the reasons stated previously. However, the analysis does illustrate why rates of population change using occupancy are inadequate for estimating trends in Mexican spotted owl populations. If nothing else, we believe the analytical procedures and framework that we have used throughout this section should provide a template for future research as well as indicate priorities for future research efforts.

Theoretical Problems with Current Monitoring Procedures

Much effort has been expended by personnel of FS Region 3 in collecting the monitoring data summarized here. Unfortunately, the monitoring effort was inadequate for detecting important changes in the population dynamics of the Mexican spotted owl because the appropriate parameters were not measured.

The primary goal of the monitoring program should be the detection of significant changes in population levels of the owl. Such changes can be caused by change in survival rates or change in reproduction, or both. The current monitoring program only examines reproduction. Occupancy rate and pair persistence are logically flawed approximations to survival. Thus, with the current monitoring system, drastic changes in the owl population could occur and not be detected; or if detected, the current monitoring system would not yield the statistical rigor necessary to substantiate the conclusion strongly enough to withstand the criticism of opponents to the suggested finding. Therefore, an improved monitoring system must be developed for future work (USDI 1995).

Figure 2.2. Changes in occupancy of formal and informal monitoring territories in the FS Region 3 monitoring database.



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CHAPTER 3: Landscape Analysis and Metapopulation Structure

Tim Keitt, Alan Franklin, and Dean Urban

Unlike the northern spotted owl (see Thomas et al. 1990), the range-wide population of the Mexican spotted owl is naturally fragmented into geographically distinct subpopulations. Thus far, we have discussed populations at the local scale within Recovery Units where individuals within subpopulations interact to some degree. Understanding population structure at larger scales is important, even though data are extremely limited at these scales for the Mexican spotted owl. Hanski and Gilpin (1991) identified two additional scales beyond the local scale: (1) a *metapopulation* scale where individuals infrequently move between subpopulations and typically cross unsuitable habitat to reach an adjacent subpopulation, and (2) a *geographical* scale where individuals have little likelihood of moving to most portions of the geographic range of their species. By definition, metapopulations are systems of local populations connected by dispersing individuals (Hanski and Gilpin 1991). The metapopulation concept has been applied to the conservation of northern (Schaffer 1985) and California (Noon and McKelvey 1992) spotted owl populations. However, on a geographical scale, the rangewide population of Mexican spotted owls may be composed of a several discrete metapopulations rather than of a single integrated metapopulation. Understanding to what degree Mexican spotted owl populations follow metapopulation dynamics is essential for managing the subspecies on all three scales.

METAPOPULATION MODELS

Theoretical work has proposed several models of metapopulations based on different mechanisms for persistence. These have been classified as the Levins model, source-sink, core-satellite, patchy, and non-equilibrium metapopulations (Harrison 1991). An important consideration when reviewing these models is that empirical evidence for the existence of the proposed mechanisms in natural populations is debatable (Doak and Mills 1994).

The Levins Metapopulation Model

Levins (1969) first introduced the metapopulation concept with a simple model. This model incorporated three essential requirements for persistence of a subdivided population: (1) density-dependent dynamics of populations, (2) asynchronous dynamics of local subpopulations in that not all subpopulations have the same rate of change at the same time, and (3) dispersal between subpopulations. Dispersal is an essential component of this, and all other, metapopulation models and provides the mechanism for recolonizing areas where local subpopulations have died out.

Source-sink and Core-satellite Metapopulation Models

In source-sink models (Pulliam 1988), source areas with self-propagating (typically increasing) populations provide a flow of recruits to sink areas where populations are not self-reproducing (and may be declining). Without the net flow of immigrants from the source areas, populations in sinks would not persist. Source-sink mechanisms can be applied to contiguously distributed populations where habitat conditions can dictate whether a population segment is a source or a sink. This mechanism can also be applied to a metapopulation of discrete subpopulations where habitat or other conditions dictate whether such an area is a source or a sink.

The core-satellite model builds on the source-sink model by having a central core population which acts as a source surrounded by a number of smaller sink populations (Harrison 1991). Persistence of the satellite populations depends upon the central source population.

Patchy Metapopulation Models

Patchy populations in the context of this model are characterized by a high dispersal potential where dispersal takes place on a spatial scale greater than the local events causing subpopulation dynamics (Harrison 1991). The patchy metapopulation model is distinguished from the Levins model in that the average individual can belong to more than one subpopulation in its lifetime (excluding its natal subpopulation). The result, in effect, is a well-mixed version of the Levins model.

Non-equilibrium Metapopulation Model

Populations characterized by this model essentially follow the same dynamics as the Levins model except that continuous recolonization of extinction-prone subpopulations has been disrupted. Essentially, this model represents metapopulations in decline even though one or more subpopulations may be stable. Instability of a formerly stable metapopulation may result from factors that affect one or more subpopulations or when contiguous populations are fragmented into discrete subpopulations. These factors can include natural (e.g., fire, disease) or anthropogenic (e.g., logging, urban development) disturbances.

DISPERSAL

In all metapopulation models, dispersal is a key component. Dispersal acts as a bridge between subpopulations at the metapopulation scale to provide immigrants to otherwise isolated habitat patches. The fate of these recruits depends on the status of the subpopulation. If the habitat patch has been unoccupied, then the new recruits "rescue" it from extinction. If the patch is not saturated with territorial breeders, the recruits might bolster the breeding population. If the patch is saturated, the new recruits might persist as nonbreeding "floaters," perhaps buffering the population against future fluctuations.

Adult and subadult Mexican spotted owls appear to be relatively sedentary once they come to occupy a given site. Juvenile Mexican spotted owls, however, almost always disperse from their natal sites (Willey 1993, Hodgson and Stacey 1994, Reynolds and Johnson 1994). If metapopulation dynamics apply to Mexican spotted owl populations, these dynamics probably hinge on the flow of juvenile spotted owls between subpopulations.

Dispersal of young Mexican spotted owls is poorly understood. Several studies have attempted to examine juvenile dispersal through radio-telemetry (Willey 1993, Hodgson and Stacey 1994, Reynolds and Johnson 1994); but sample sizes have been small. Total distances moved by 7 juveniles radio-marked in Utah (Willey 1993) ranged from 32 to 98 km (20-61 miles) (median = 41.8 km [26 miles]). Four of these juveniles moved back to within 8 km (5 miles) of their natal area just prior to the breeding season. Hodgson and Stacey (1994) also reported 2 juveniles dispersing between the San Mateo and Black Mountain Ranges of New Mexico, distances of 45 and 58 km (28-36 miles). In addition, dispersing juveniles crossed large expanses of habitat typically considered unsuitable for resident spotted owls. Reynolds and Johnson (1994) radio-marked 6 juveniles, none of which were relocated beyond their natal site. The radio-telemetry data suggest that juvenile owls have the dispersal capability to act as recolonizers between many of the subpopulations and to provide genetic links between subpopulations. Thus far, none of the radio-marked juveniles have been recruited into a resident, territorial subpopulation.

With source-sink and core-satellite metapopulation mechanisms, juvenile owls from source areas must not only reach isolated subpopulations but do so in sufficient numbers to stabilize sink populations. We examined straight-line distances moved by 25 juveniles banded from 1991 through 1993 on the population study areas (CSA and GSA) which had been recaptured as territorial subadults and adults (R.J. Gutiérrez, D. Olsen, and M. Seamans, Humboldt State Univ., Arcata, CA, pers. comm.). From these data, we generated a probability function by fitting an exponential curve to distances moved and the cumulative probability that juveniles had moved at least those distance (Figure 3.1). This curve represents the probability that a juvenile will disperse at least a given distance and be recruited into the territorial population. This curve can also be viewed in terms of proportions. For example, about 60% of the juveniles would be expected to disperse at least 10 km (6.2 miles) and be recruited into the population. We provide this information as an illustration of the type of data needed to assess the role of dispersal in metapopulation dynamics. The data we used were not designed to generate such a curve and may be artificially truncated because of lower search effort for banded recruits in the larger areas surrounding each of the study areas. Such an effect can be responsible for the exponential nature of the relationship in Figure 3.1 and underestimate true dispersal distances.

APPLICATION OF LANDSCAPE ECOLOGY

Landscape ecology is concerned with the development, implications, and dynamics of landscape pattern. We use the term "pattern" generously, but here we are concerned especially with three components of pattern: (1) the size distribution of habitat patches; (2) the spatial orientation of these patches with respect to each other, that is, their juxtaposition; and (3) their mutual distance relationships as these might influence spotted owl dispersal.

With respect to metapopulation dynamics, landscape analysis is concerned with distance relationships among habitat patches as these might affect the relative isolation of certain patches or regions of patches within the owl's range where patches may correspond to distinct subpopulations. The issue of so-called patch "connectedness" is central to current ideas about metapopulation dynamics. By conventional definition, two patches are functionally connected if individuals can disperse between them with a probability or frequency above some minimum threshold value. We will further define connectedness to incorporate patch area as well as between-patch distance relationships (see below); thus, a patch may be highly connected if it is near several small patches or near one large patch. Specifically, we have two concerns about patch connectedness:

1. Can we identify habitat patches that because of their area and position within the landscape might play a particularly important role in overall landscape connectedness? We expect large habitat patches to be important in this analysis.

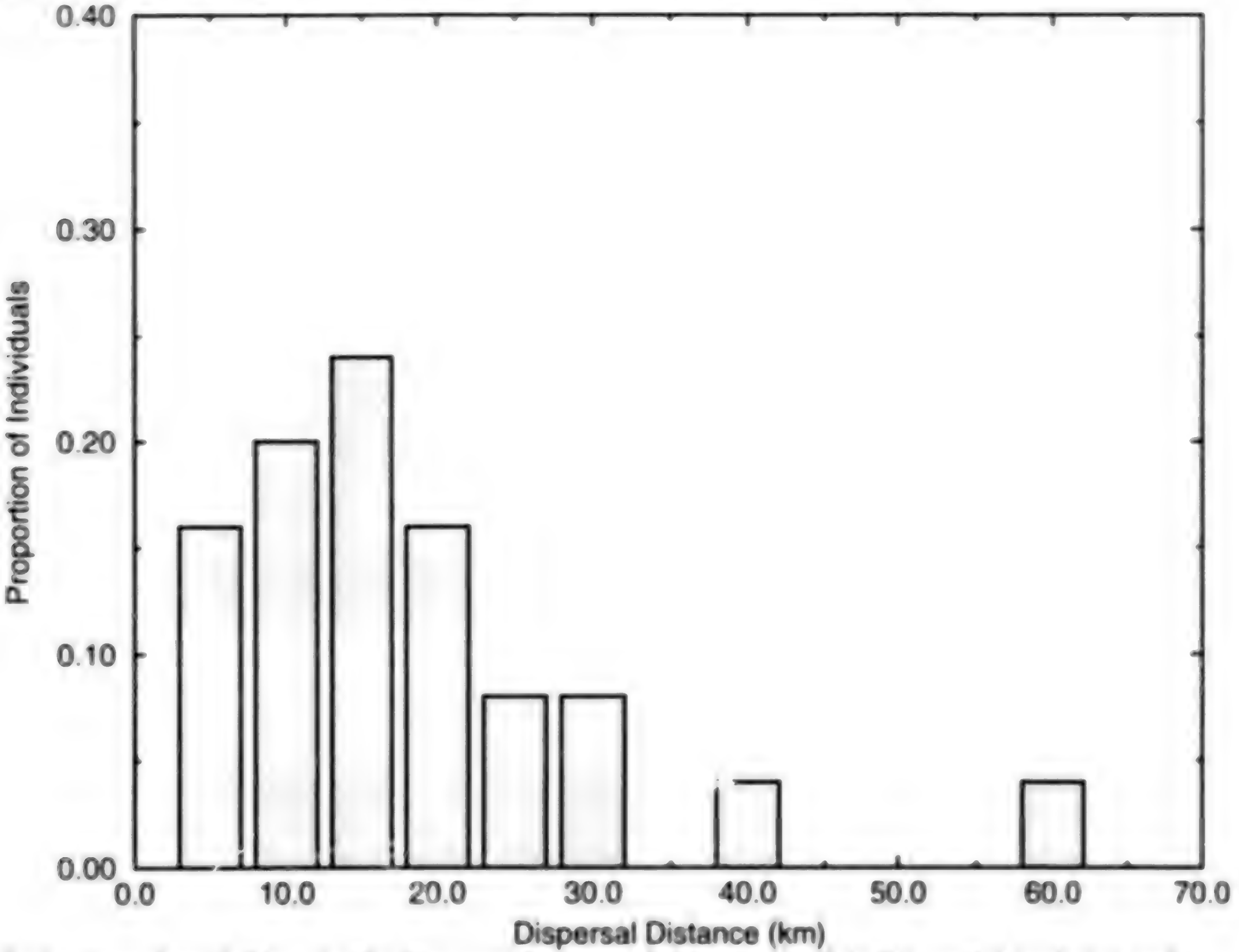
2. Are there habitat patches that might be critical to landscape connectedness chiefly because of their spatial position, that is, despite their smaller size? These might function as dispersal conduits or small "stepping stones" within the landscape.

The goal of this set of questions is to identify habitat patches that might influence patterns in owl distribution well beyond their immediate location. In the case of a small stepping-stone patch, this importance might be despite its having rather modest owl populations. Thus, critical patches identified in the landscape analysis might warrant special consideration in the Recovery Plan even though their local populations might not elicit any special concern.

Scale and Resolution in Landscape Analysis

Landscape analysis typically connotes rather large spatial scales. In our analyses, we have identified two spatial scales of interest. At a smaller scale we are concerned with areas such as a single National Forest, a scale defined in large part by administrative criteria. At a larger scale we are concerned with the geographic range of the owl as we defined it in this plan. We will refer to these scales as "forest" and "rangewide." Importantly, habitat data available at these two scales is of very different resolution. Data at the forest scale are of higher spatial resolution (smaller grain size) and often of higher information content as well, while data at the rangewide scale is coarser-resolution and makes fewer

Figure 3.1 Dispersal-distance relationship for radio-marked juvenile spotted owls.



distinctions about habitat details. For example, many forests have digital elevation models (DEMs) with a nominal resolution of 30 m (98 ft) and habitat data corresponding to timber-management compartments resolved on the order of tens of hectares. At this scale, habitats may be defined in terms of tree-species composition, size-class distributions, or other details. By contrast, the data we have available for rangewide analyses have a spatial resolution of 1 km (0.62 miles); habitats at this scale are defined as gross cover types (e.g., pinyon-juniper). Data at these two scales lend themselves to the same analytic techniques but require rather different interpretation because of their different resolution and information content.

Data Availability

In keeping with the foregoing discussion of scale and resolution, we have attempted to acquire data at two scales and resolution for landscape analyses. At a finer scale, we sought USGS DEMs with 30-m (98 ft) resolution and habitat maps of similar spatial resolution and comparatively high information content (e.g., species composition, size-class distributions). We were largely unsuccessful in this effort and, thus, have been unable to address questions on spatial aspects of habitat use by owls at this scale.

At a coarser scale, we acquired two sets of habitat data. Both sets were derived from AVHRR satellite imagery and have a spatial resolution of 1 km^2 (0.39 miles^2). One set is the EROS Land Cover classification (Loveland et al. 1991), which recognizes 159 cover classes across the conterminous United States. The second dataset is derived from the EROS set but was reclassified by the FS into a smaller number of recognized Forest Cover Types (Powell et al. 1993, Zhu and Evans 1992, Evans and Zhu 1993). This latter set also includes a companion coverage of forest density (percent canopy cover) derived by resampling the AVHRR-based data with higher-resolution Thematic Mapper (TM) imagery at 30-m (98 ft) resolution and correlating the percent of cells forested at 30-m (98 ft) resolution to a greenness index (NDVI) at 1-km

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resolution (Zhu 1994). The FS has also created a preliminary classification of Mexico's forest cover types, based on the same AVHRR imagery (Evans et al. 1992). No forest density coverage exists for Mexico at this time. Examination of these coverages revealed that the EROS classification included too much detail and some details that were rather suspect from a biogeographic standpoint, both of which argued against its use. The FS coverages span the entire range of the owl within the United States and at an appropriate information content (number of classes). For these reasons, we have elected to base our rangewide analyses on the FS coverages. At this scale, we also have 1-km^2 (0.39 miles^2) resolution DEMs as provided by EROS. Because we lack comparable data for Mexico, our analyses are restricted to the United States.

The lack of data at higher resolution (e.g., 30-m scale) has important implications in our analyses, in that it precludes analysis of those features too fine-grained to be resolved in the coarse-resolution data we have been forced to use. For example, the 1-km scale data cannot resolve small canyons that are important to owls in parts of Utah. Neither do we have data that can resolve details about owl microhabitat, nor even subtle distinctions among forest cover types. As we note below, this lack of data does not render our analyses pointless, but it does emphasize the need to repeat and corroborate these analyses with finer-resolution data. On the other hand, our coarse-resolution approach allows us to analyze landscape pattern over virtually all of the owl's range within the United States.

Landscape Connectedness

Our approach derives from graph theory and percolation theory (Gardner et al. 1992) and focuses on the so-called "radius of gyration" of the largest subgraph in a graph representing a landscape of habitat patches. In this, a "graph" is a set (map) of habitat clusters, and each "cluster" is a collection of grid cells that are defined to be functionally connected. In practice, we define this connection based on a "minimum joining distance" such that cells that are within this distance are functionally connected. The radius of gyration is defined as the mean Euclidean distance between each cell of a habitat cluster and the centroid of that cluster. Habitat clusters are formed by specifying a joining distance and then identifying groups of cells that are spatially discrete at that distance scale. As one increases this joining distance, the habitat map coalesces into increasingly larger clusters as isolated patches are subsumed into nearby clusters. A convenient means of indexing this process is as the radius of the largest cluster in the graph. A weighted index for the map can be computed by summing the radii of all clusters in the map, weighting each radius by the proportion of the entire map it comprises (i.e., its relative size). This weighted sum is the map's "correlation length" (or connectedness length) and has as units the distance units of the original map. One interprets correlation length in terms of how far, on average, an animal could traverse the map without straying off "habitat" cells into nonhabitat.

The ultimate goal here is not to compute landscape connectedness in itself, but rather to identify those patches (clusters) that contribute most significantly to overall habitat connectedness. One means to this end is to estimate the reduction in connectedness that would result if a patch were removed from the landscape. Here, this estimate is computed as the reduction in correlation length of the landscape. These reductions are estimated by systematically removing each cluster and recomputing the connectedness index. The analysis itself proceeds in steps as follows:

1. Define a binary raster map of "habitat" versus "nonhabitat."
2. Specify a distance threshold at which patches may join.
3. Perform the cluster-removal experiment, saving each cluster's effect on the correlation length.
4. Normalize this effect for each cluster by dividing its effect by its total area, and save this value as well.

The normalization in step (4) adjusts the patch's effect for its area, which identifies those patches whose effect on connectedness is large relative to their size. The result of the analysis is a ranking of habitat patches in terms of the reduction in connectedness each elicits, that is, each patch's contribution to overall connectedness.

This procedure is then repeated for a range of threshold distances to estimate the consequences of varying assumptions about the dispersal capabilities of owls. We used distances from 0 to 100 km (0-62 miles) in 5-km (3.1 mile) intervals. This range spans our best empirical estimate of the owl's dispersal range, which is on the order of 50 km (31 miles). If the patch ranks change considerably at different joining distances, this would suggest a need to improve the accuracy of our estimates of owl dispersal distances so that we could tailor the analysis to maximize its biological significance.

Finally, the entire analysis is repeated for a variety of baseline habitat maps. This gives us an estimate of how robust the results are to assumptions about what constitutes "potential owl habitat." At this spatial scale and with the data available, we have limited opportunities to devise alternative definitions of "owl habitat." We have devised three alternative habitat maps:

1. A map wherein all cells assigned as "Douglas-fir" (i.e., mixed conifer) or ponderosa pine (including some mixed-conifer as well as pine-oak) cover types are defined to be potential owl habitat;

2. A map including all Douglas-fir and ponderosa pine cells, plus any pinyon-juniper cells that have greater than 50% canopy cover as estimated in the FS Forest Density coverage;

3. A map including all Douglas-fir and ponderosa pine types, plus those pinyon-juniper cells that are within a 2-km (1.2 miles) buffer of Douglas-fir or pine types, i.e., pinyon-juniper near better owl habitat.

These alternative definitions vary in terms of how narrowly or generously "habitat" is defined. Other definitions could certainly be devised, and we do not argue that ours are the only (nor even the best) possibilities. We will argue, however, that these are sufficient to indicate whether our conclusions are robust to the definition of habitat or whether we need to invest more effort in generating more realistic base habitat maps.

Results of Landscape Analyses

Results of these analyses provide insight into two keys aspects of habitat connectedness: (1) the relationship between minimum joining distance and overall connectedness as indexed by correlation length; and (2) contributions of individual habitat patches to overall connectedness. We present each of these in turn. Because the results were qualitatively similar for each of the baseline habitat maps, we present here only the results for the mixed-conifer/ponderosa pine base map; but we return to this issue later in our discussion.

Landscape Connectedness and Minimum Joining Distance

Correlation length exhibits a profoundly nonlinear relationship with minimum joining distance in all cases we examined (Figure 3.2). The inflection in this relationship illustrates that the landscape changes from being largely "unconnected" to largely "connected" over a narrow range of distances. In the habitat maps we analyzed, this transition occurred over distances of 40-60 km (25-37 miles). This result varied only slightly for alternative habitat maps, suggesting that this qualitative result is rather robust to these definitions.

The relationship between cluster size and joining distance varies systematically with the spatial resolution with which habitats are defined. This can be seen most clearly by contrasting the curve for "all clusters" of ponderosa pine and Douglas-fir as compared to the curve for the largest 254 of these clusters (Figure 3.2). Including more (smaller) clusters shifts the curve to the left, effectively joining the landscape at closer distances. Presumably, if we were to include very small clusters the landscape might be functionally connected at extremely small joining distances, which is something of a scaling artifact. This result does underscore the need to more fully characterize the habitat affinities and dispersal behavior of owls. If we could limit cluster sizes and joining (dispersal) distances to biologically reasonable values, this analysis would be more confidently focused.

All habitat maps coalesced into a very few large clusters at joining distances of approximately 60 km (37 miles) or more. This indicates that at these distances, the entire landscape is essentially connected (Figure 3.3). Yet even at joining distances of 100 km (62 miles), a few clusters remain spatially discrete, and by implication, functionally isolated from the rest of the habitat in the landscape.

Rank Patch Contributions to Connectedness

The influence of each patch on overall connectedness was tallied for only the largest 254 clusters in each map. In fact, the maps contained thousands of clusters but many were single cells; so it proved to be computationally impractical to compute every case. Patch influence on correlation length was strongly dependent on joining distance: the average influence was greatest at intermediate distance scales and much less at shorter or longer scales (Figure 3.4). To highlight influential patches spatially, we produced a habitat map in which each patch is color-coded according to its mean rank over all distance classes (Figure 3.5a). A similar map emphasizes patch importance to connectedness at the intermediate distance scale of 45 km (28 miles) (Figure 3.5b). In both maps, "hot" colors indicate highly ranked patches (those contributing substantially to landscape connectedness) while "cool" colors indicate patches of low rank (those with little effect on connectedness).

In general, patch effects on connectedness depended on patch area, in that large patches had the greatest influence on overall connectedness. Patch ranks, normalized for area, are illustrated as averaged over all distances (fig. 3.6a) and at 45-km (28-mile) joining distance (Figure 3.6b), using the same color scheme as in Figure 3.5. These figures emphasize the importance of a few clusters in joining the large habitat block along the Mogollon Rim to the large cluster farther northeast.

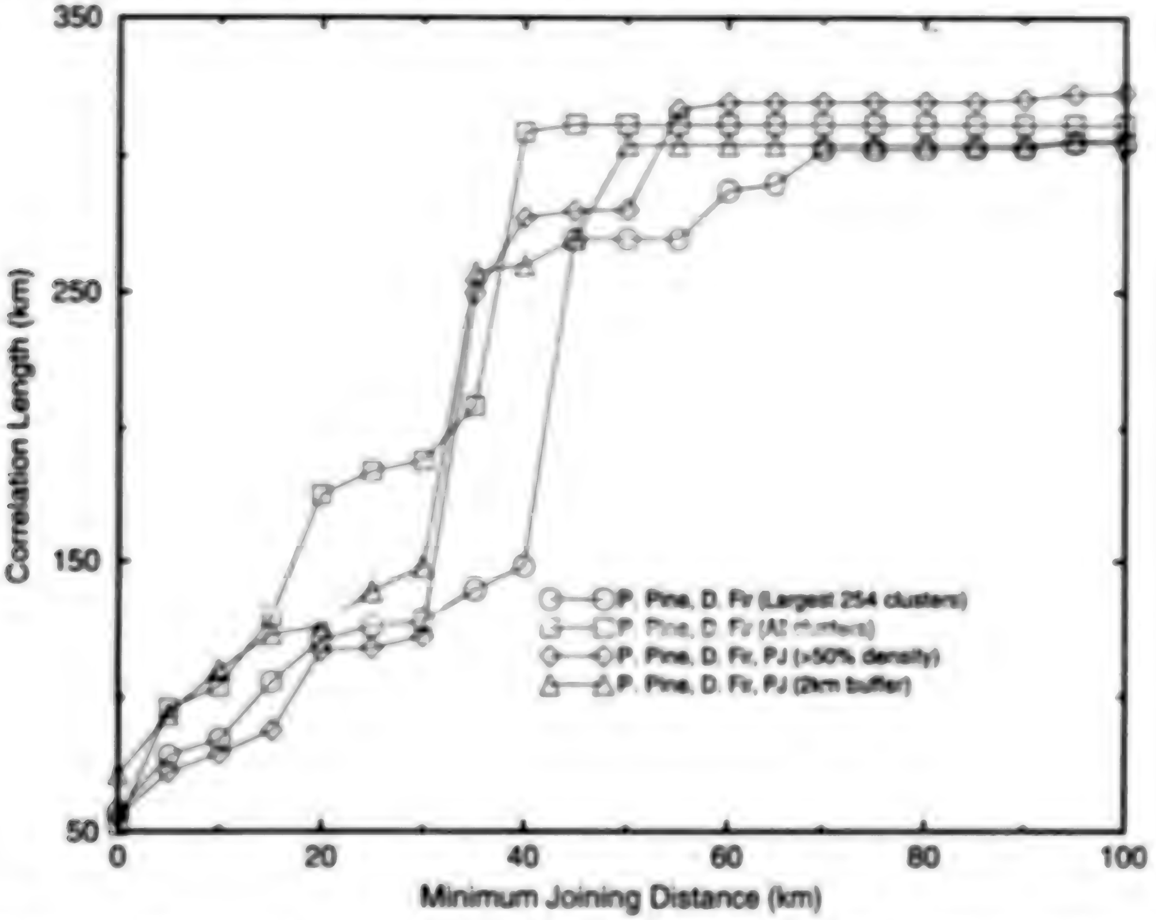
DISCUSSION

Distance Relationships in Landscape Connectedness

The nonlinear relationship in Figure 3.2 makes intuitive sense if one envisions the process that generates this relationship. At small joining distances, small and nearby patches are joined into somewhat larger clusters, but the landscape still consists mostly of disjoint clusters. At a particular distance, a large subset of the clusters joins into a single large cluster. Once this has happened, further small accretions to the cluster do not change its total area appreciably. From a functional standpoint, these later additions are redundant links to an "already connected" cluster. This same process explains why the graph of average influence of patch removal (Figure 3.4) shows a peak at these intermediate distance classes; for shorter or longer distances these patches can have little impact on overall connectedness.

An important result of this analysis is that the strongly nonlinear domain of this relationship (i.e., the inflection point in Figure 3.2) coincides with our best current estimate of the dispersal capabilities of spotted owls based on field studies, approximately 50 km (31 miles). By implication, if owls' dispersal ranges were much less than this estimate (say, 20 km [12 miles]) then much of their natural range would be functionally unconnected (most patches would be isolated). Reciprocally, if owls could disperse much farther than our current estimate (say, 100 km [62 miles]), then most of the landscape would be functionally connected. Likewise, the change in this relationship with the inclusion of more, smaller patches suggests that owls' use of very small patches as dispersal conduits or stepping stones could influence these results. If owls can use very small patches, then the landscape might be more connected than our

Figure 3.2. The relationship between correlation length and minimum joining distance. The 4 lines illustrate the efects of alternative definitions of "potential owl habitat."



results suggest, presuming, of course, that such small patches exist.

The radio-telemetry data suggest that juvenile owls have the dispersal capability to provide population and genetic links between subpopulations. To date, none of the radio-marked juveniles has been recruited into a resident, territorial subpopulation. In attempting to judge whether owl dispersal is sufficient to maintain population and genetic connectedness, we are faced with the logistical problem that ecologically significant dispersal events might occur quite infrequently (1-2 per generation) and would likely go unrecorded by even the most intensive monitoring program. Thus, our data can suggest that such dispersal capabilities might exist, but these data cannot prove that such dispersal actually occurs. Importantly, neither can our lack of data prove that such dispersal does not occur.

Clearly these results point to a need for better understanding of the dispersal behavior and distance relationships for spotted owls. One source of uncertainty in our analyses is that the clustering is based on boolean distance decisions (i.e., patches are connected if their distance is strictly within the joining distance). But animal dispersal is probabilistic, exhibiting some sort of decreasing probability with increasing distance (recall Figure 3.1). This distinction exaggerates our results relative to how dispersal probably occurs with real animals.

A second source of uncertainty stems from our limited understanding of owl dispersal behavior. Our analyses are based on assumptions about "reachability" with the tacit assumption being that if habitat is reachable in terms of absolute distance, then owls can and will disperse there. But there are many plausible reasons why this might not be so (e.g., avoidance behavior, excessive mortality during dispersal); so it remains that we need to temper our interpretations with additional considerations of owl dispersal.

Figure 3.3. Landscape mosaics of discrete clusters of Douglas-fir and Ponderosa pine habitat types, as (**a**) largest 254 clusters, and at (**b**) 30-km, and (**c**) 60-km joining distances. Colors have no significance beyond labelling discrete clusters.

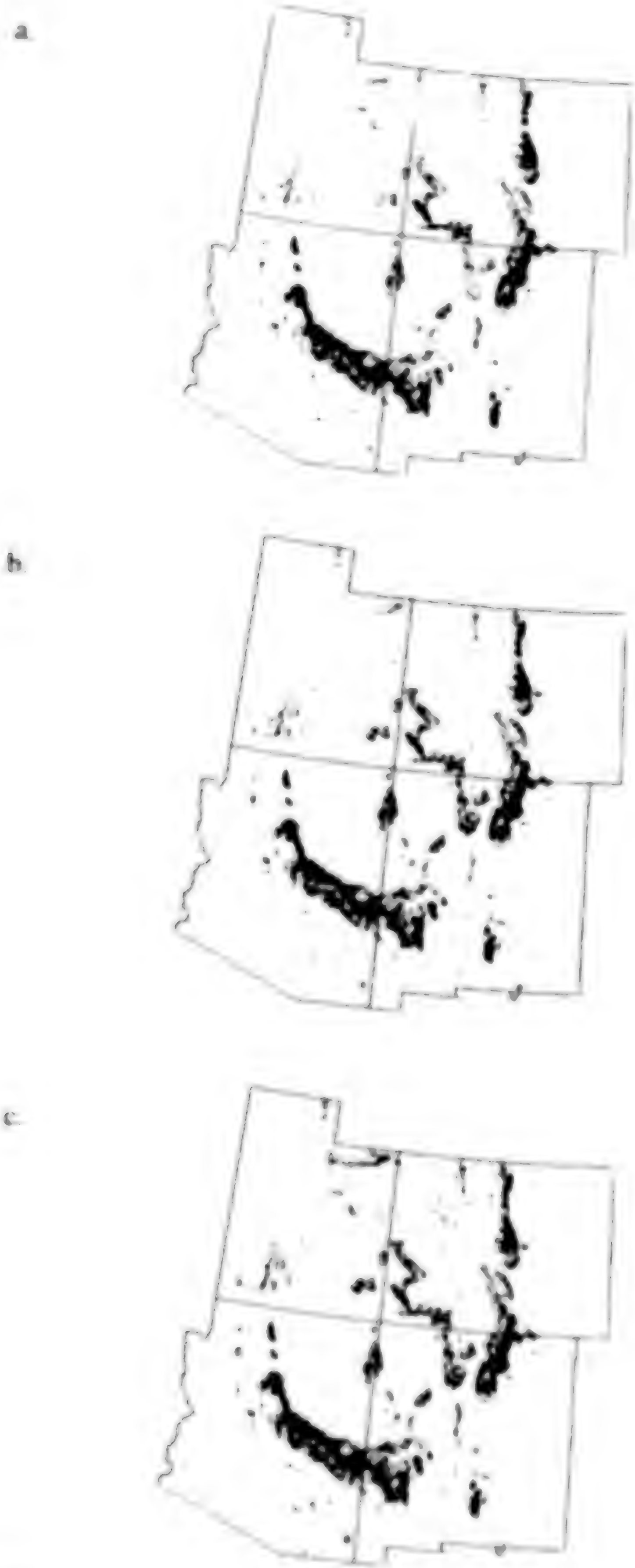


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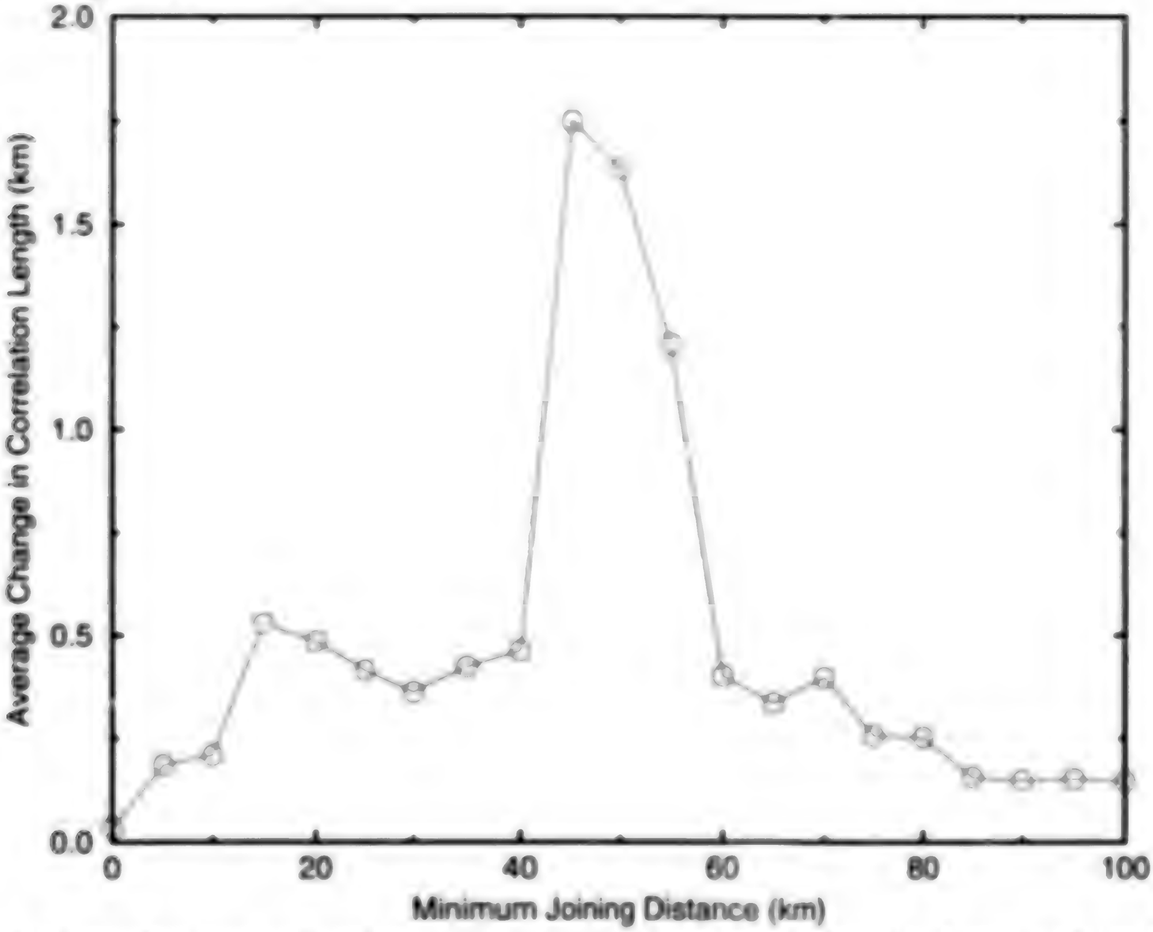
Figure 3.4. Change in correlation length due to cluster removal as a function of distance, averaged over the largest 254 clusters.



Patch Contributions to Landscape Connectedness

Rank scores for patch contributions to overall landscape connectedness make intuitive sense when viewed as landscape mosaics (Figures 3.5 and 3.6). The ranks uncorrected for area show the expected result that large clusters that are centrally located have the highest ranks, while small or isolated clusters are lower-ranked. Area-normalized ranks emphasize the positional aspects of patch contributions and Figure 3.6 illustrates a few patches (in red) that seem to act as bridges spanning larger habitat areas. Some of these bridges are rather small yet could be important links in landscape connectedness.

An important caveat to bear in mind is that these analyses are all based on habitat, not on owl densities. Thus, sparsely populated habitat clusters in the northern reaches of the owl's range receive equal weight in the analysis as compared to habitats currently supporting much larger owl populations, for example, along the Mogollon Rim. Thus, the clusters in Colorado that appear important to connectedness (red patches in the upper-right regions of Figure 3.5) are actually connecting habitat that supports essentially no owls. If habitat clusters were weighted according to present-day owl abundance, these same analyses would provide quite different results. Densely populated patches would increase in importance while more sparsely populated patches would be down-weighted. While this is rather easy to anticipate in general, such a weighted analysis would require much better spatial information on owl abundance across its range than the inconsistent coverage currently available.

These considerations bear strongly on the ultimate goal of a conservation plan. If our goal is to provide a template that might sustain owl metapopulations well into the future, then an analysis weighted on "potential habitat" seems most appropriate. Conversely, a strategy to preserve current populations would seem to argue for an analysis heavily weighted on present-day owl abundance. Our results suggest

Figure 3.5. Maps with clusters colored to illustrate their rank importance, weighted by (uncorrected for) patch area. Hot colors (reds) are highly ranked; cool colors (blue-violet), low ranked. Base habitat map is ponderosa pine/Douglas fir. **(a)** Patch importance averaged of all distance classes. **(b)** Importance at 45-km joining distance.

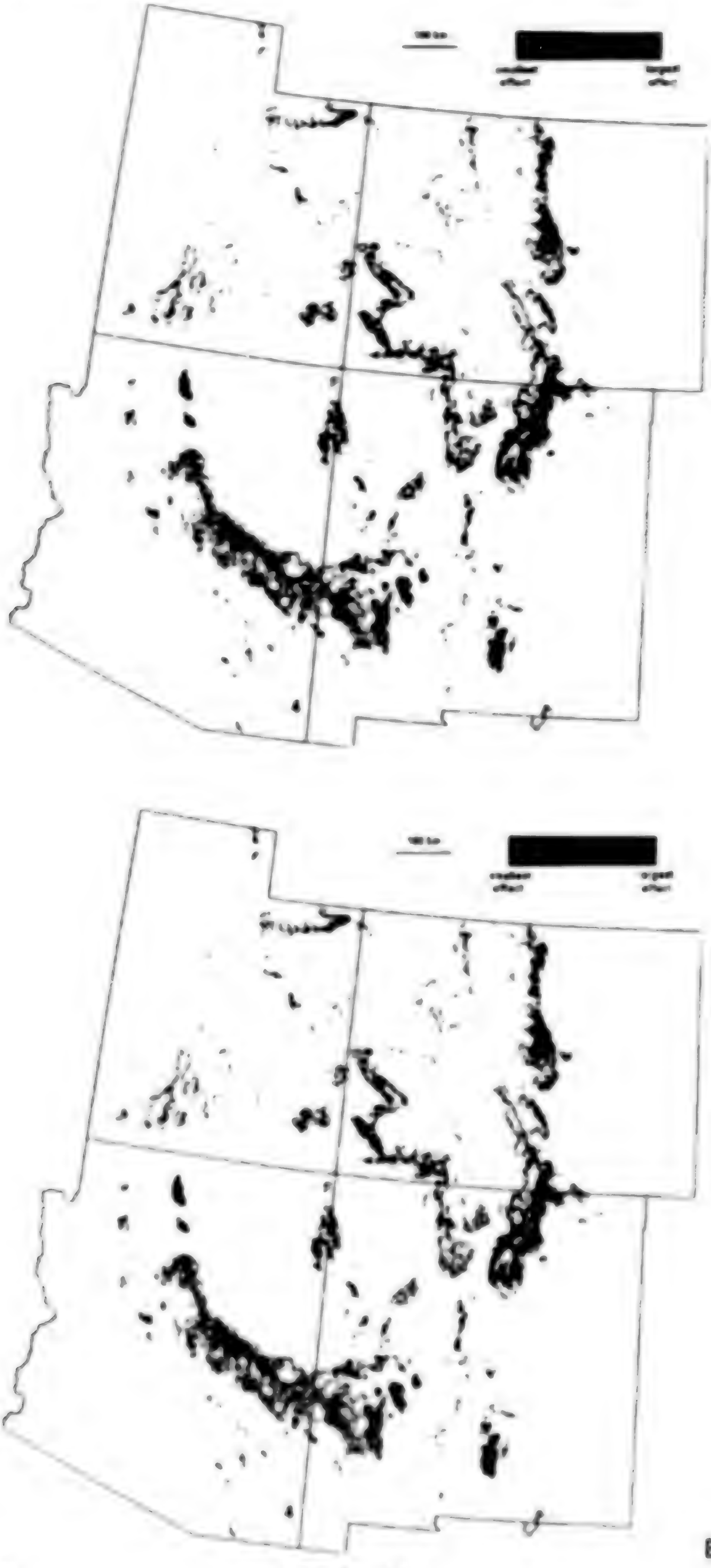


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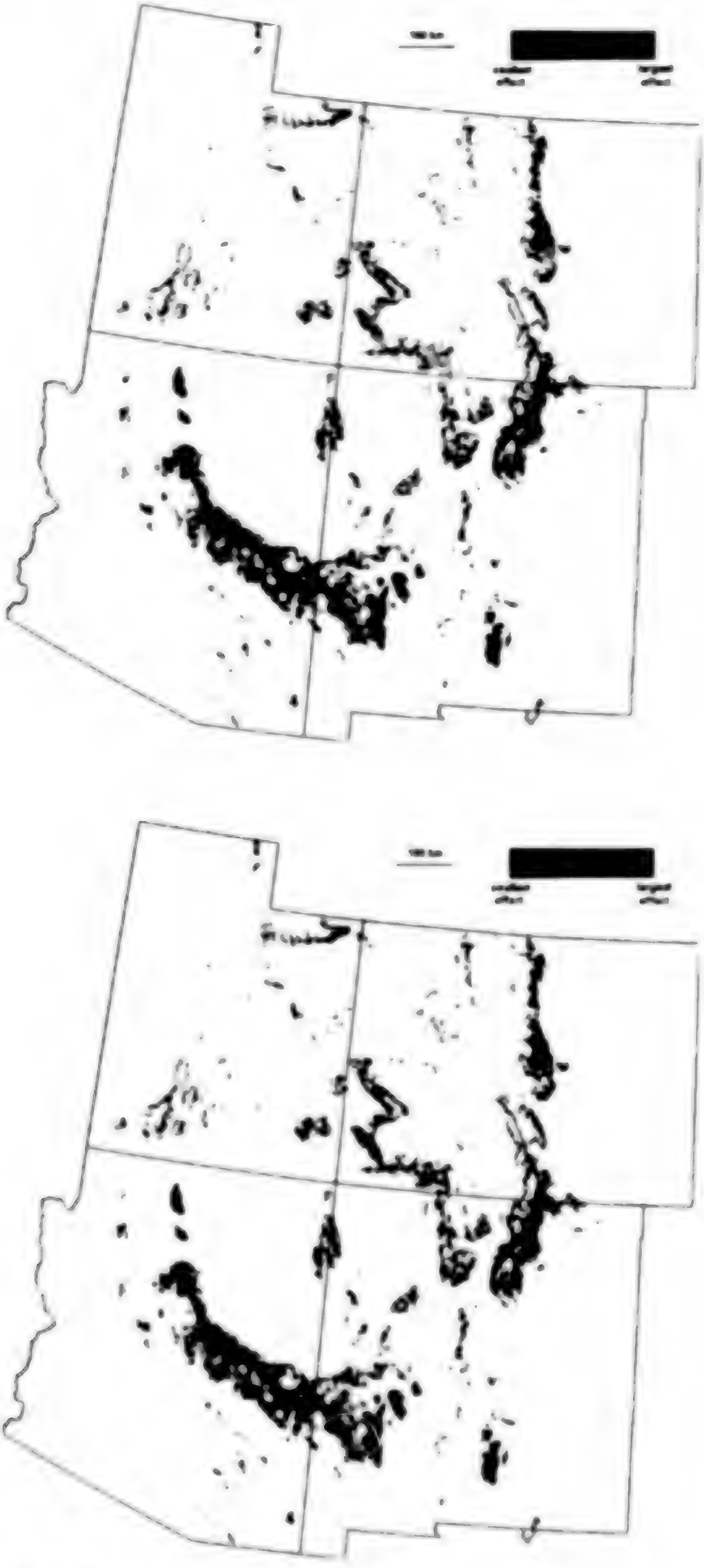
Figure 3.6. Patch importance to overall connectedness, normalized for patch area. Color scheme and base map, and panels (**a**) and (**b**), are the same as in Figure 3.5.



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that these two strategies might lead to quite different recommendations.

Importantly, our rankings of patch importance to overall connectedness are based on a simple patch-removal algorithm in which each patch is removed singly from the existing landscape. Clearly, these results could be quite different if the algorithm provided for more complex scenarios as conditional removals. For example, if patch *i* has already been removed, then the removal of patch *j* might take on much greater importance. Such conditional scenarios would be more realistic in the sense that landscape dynamics driven by land-use management are time-structured (sequential), conditional, and typically act on multiple patches during any single management episode. Such complicated scenarios might be undertaken on a smaller scale (e.g., for a National Forest) if sufficient data were available for the analysis. Complicated, conditional scenarios are probably not feasible for rangewide analyses.

Sensitivity to Habitat Definition

Two empirical biases emerge in considering alternative definitions of what constitutes "potential owl habitat" in these analyses. One bias is due to the spatial scale at which habitat patches are resolved. As smaller patches are included, overall landscape connectedness tends to increase so long as these small patches are liberally sprinkled across the landscape. Similarly, for habitat definitions that are increasingly "generous" toward owls, more potential owl habitat occurs in the landscape and so connectedness also tends to increase (consider a map that includes some pinyon-juniper relative to the mixed-conifer/pine landscape). These biases appear in our analyses as a result of data availability. If higher-resolution data were available, more patches could possibly be delineated. At the same time, however, given higher-resolution data we could define owl habitat more stringently and thus some patches would be redefined as no longer usable by owls; owl habitat would decrease in abundance and overall connectedness would decrease accordingly. Thus, the two empirical biases are somewhat compensating. But both biases point to a need to improve our ability to discriminate usable owl habitat from the surrounding matrix.

Other Uncertainties and Considerations

A final consideration of our results must address any uncertainties or biases that might result from the algorithm itself. One potential bias that emerges can be seen in the figures illustrating patch importance to connectedness. Because our approach indexes connectedness as the mean size of the largest cluster, a bias emerges whereby patches that are peripheral in the landscape can form clusters with a very large radius. Thus, the important patches in Figure 3.5 tend to form a ring around the landscape as a whole, partly because these patches are large but also because their joining creates a cluster that has a radius nearly as large as the entire mosaic. This bias would not occur if the index of connectedness counted total area in a way that did not emphasize among-cell distances. For example, an index that estimated "total connected area" rather than the effective size of this area might yield a slightly different estimate of patch importance. Unfortunately, such indices have proven to be computationally unfeasible thus far. We continue to explore alternative algorithms for indexing habitat connectedness.

CONCLUSIONS

Application of metapopulation theory to the Mexican spotted owl is rather speculative, given our limited understanding of within-population dynamics much less between-population dynamics. If metapopulation models actually represent realistic abstractions of real-world processes, then a number of different metapopulation models may apply to different geographic regions within the range of the Mexican spotted owl. For example, one could envision a core-satellite model applying to the southern portion of the Mexican spotted owl range with the Upper Gila RU acting as a core source population with the smaller surrounding mountain ranges in Basin and Range - West and Colorado Plateau RUs acting as satellite sinks. On the other hand, the Sky Island mountain ranges in southern Arizona could also follow the classic metapopulation dynamics proposed by Levins (1969). A number of different scenarios could be envisioned, which, unfortunately, we cannot corroborate easily empirically. The distribution of geographically isolated subpopulations, however, suggests that some form of interaction between these subpopulations is plausible. Clearly, intensive, long-term studies over large areas will be required to understand the structure and dynamics of Mexican spotted owl population at these large scales.

Although the landscape analyses are exploratory, some general conclusions can still be drawn from the results. These conclusions concern apparent connectedness of various regions of the owl's range and the relative importance to particular habitat clusters to overall landscape connectedness.

Regardless of the underlying habitat map used in analyses, results consistently show a few regions that appear functionally isolated at intermediate joining distances similar to the dispersal range of owls. For example, large blocks of southern Utah persist as discrete habitat clusters at joining distances of 40 km (25 miles); the Lincoln National Forest also appears isolated at this spatial scale. We might test the hypothesis that these subpopulations are discrete, possibly by exploring genetic similarities between these and more central (connected) populations such as those along the Mogollon Rim. Likewise, basic population analyses of these populations might also indicate their degree of functional connectedness. For example, spatial discontinuities in population density, age structure, or other parameters might suggest that these populations do not interact to the same extent as other, more contiguous populations.

The relative importance of individual habitat patches, when uncorrected for patch area, suggests the intuitive approach of protecting those patches that currently support the highest owl densities, such as along the Mogollon Rim. But our results also indicate a high importance for patches farther north in the owl's range, patches which currently do not support appreciable owl populations. Our reaction to this result depends in part on whether our goal is to preserve present-day populations or to protect the capability for populations to expand in the future. The discrepancy between these two strategies is most pronounced in the northern reaches of the owl's current range.

Correcting cluster importance for area indicates the contribution, per unit area, of each of the habitat clusters. This correction suggests that while the cluster along the Mogollon Rim is crucial to overall connectedness, the many stands making up this cluster are not so important on an individual basis. Thus, this cluster would likely continue to play an important role in the landscape so long as its internal continuity is maintained, which would require reiterating our analyses on a finer spatial scale and resolution as management of this region proceeds. Conversely, a few clusters emerge as being more important per unit area than their uncorrected importance would suggest, such as the stepping-stones evident in Figure 3.6 as red patches. Such patches warrant special attention in land use planning because of their potential to affect regional populations despite their small size and perhaps modest owl populations. Especially, these patches should be a focus of monitoring efforts so that their use by owls can be assessed. Note that these patches typically would not be targeted in field studies for the simple reason that they would not appear to support large owl populations.

Finally, we should emphasize that these results are exploratory and therefore subject to corroboration. One form of verification could come via analyses of owl subpopulations across the region. Metapopulation theory suggests that isolated habitats should show higher year-to-year variability in population density than would better-connected patches, which would be better subsidized by dispersal. A second form of corroboration would entail analyses similar to ours but using alternative indices of connectedness and alternative definitions of suitable owl habitat. Especially, we would like to see these analyses repeated with higher-resolution habitat data capable of resolving the those features most important to owls. In any case, it is clear that we need to invest much more effort toward defining the dispersal capabilities and behavior of the spotted owl across its range.

In closing, we would like to revisit the rationale that underlies our somewhat theoretical, habitat-based approach. While it might be appealing to invoke analyses that rely on owl population data, we were forced to accept at the beginning that we lacked adequate data for such an analysis across the owl's range. Similarly, detailed population models such as those developed for the northern owl are appealing because of their biological richness; but we clearly lack the data to parameterize such a model for the Mexican spotted owl. We see both these population-based approaches as a useful adjunct to our approach, but one that we cannot support empirically with data currently available. Instead, we developed an approach that makes very few assumptions about owl biology, and we tested our results to determine whether violation of these assumptions would change our results substantially. Our approach was to use as generous a definition of owl habitat as possible given our data; our major conclusions seem largely unaffected by alternative definitions of habitat, although this needs to be verified with finer-resolution data. The other important assumption we made was that owls have a dispersal-distance relationship such that dispersal probability decreases with increasing distance, and that their average dispersal is in the neighborhood of 50 km or so (i.e., not << 10 km, and not >> 100 km). Within this domain, our results are also robust. Thus, while there remain a number of questions still to be resolved concerning landscape-scale patterns and owl metapopulations, the results we present here are a useful and valid first approximation.

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CHAPTER 4: Habitat Relationships of the Mexican Spotted Owl: Current Knowledge

Joseph L. Ganey and James L. Dick, Jr.

The Mexican spotted owl was listed as threatened primarily due to concerns over loss of habitat (USDI 1993). Consequently, understanding the habitat relationships of the Mexican spotted owl is critical to developing sound management plans for this species. Here, we summarize both recent and historical information on habitat relationships of Mexican spotted owls. Because most historical information on the owl's habitat contains little quantitative information, we rely mainly on recent information (1985 - present time).

Our primary objectives in this treatment are to: (1) evaluate and describe patterns of habitat use by Mexican spotted owls; (2) evaluate and describe patterns of habitat selection by Mexican spotted owls; (3) identify specific habitats or habitat components that appear to be particularly important to the owl; and (4) identify areas where further information on habitat relationships of this owl are most needed. We use the terms habitat, habitat use, and habitat selection as defined by Block and Brennan (1993). Thus, habitat as used here refers to "the subset of physical environmental factors that a species requires for its survival and reproduction" (Block and Brennan 1993:36). Habitat use refers to "the manner in which a species uses a collection of environmental components to meet life requisites", and habitat selection refers to "disproportional use of environmental conditions" (Block and Brennan 1993:38).

Patterns of habitat use evaluated here are largely descriptive. We evaluated patterns of habitat selection by comparing use of vegetation types or specific habitat components to the occurrence of those types or components. Ecological patterns and processes vary with spatial scale (Urban et al. 1987, O'Neill et al. 1988, Turner 1989), however, and considering patterns of resource use at only one scale can yield misleading results (Porter and Church 1987, Orians and Wittenberger 1991, Block and Brennan 1993). Therefore, we used a number of data sources, both published and unpublished, to examine habitat use and/or selection at five spatial scales. At some scales we could evaluate habitat selection, whereas at others we could only describe patterns of habitat use. Scales examined are described below, arrayed from coarsest to finest scale:

1. Landscape scale - habitat use across the entire range of the Mexican spotted owl.
2. Home-range scale - patterns of habitat use within owl home ranges as defined by locations of radio-tagged owls.
3. Stand scale - use of relatively homogeneous units of forest vegetation within owl home ranges.
4. Site scale - habitat use proximate to nest, roost, and foraging sites.
5. Tree scale - use of individual roost and nest trees.

In some cases, we reanalyzed existing data sets to provide more detailed information or to explore different questions than those asked by original investigators. Methods varied among studies, and will be discussed in conjunction with the specific data examined. Some of the data used were from ongoing studies, and some of the analyses are preliminary. Therefore, while the information presented here represents the current state of knowledge on habitat relationships of Mexican spotted owls, we caution that additional trends may emerge with further data collection and analysis.

PATTERNS OF HABITAT USE AT THE LANDSCAPE SCALE

Literature Review

Available historical information on habitat use by Mexican spotted owls in Arizona and New Mexico was reviewed in Johnson and Johnson (1985), Ganey (1988), Ganey et al. (1988), and Skaggs (1988), and summarized across the range of the owl in McDonald et al. (1991). Most reports of Mexican spotted owls in both popular and technical literature are anecdotal and contain little detailed information. These reports were typically results of faunal surveys that reported areas where they found species. As such, they were neither systematic nor complete samples, and are thus biased towards the few places where spotted owls were located. While these reports provide some information on areas where owls were located, they should not be viewed as the ultimate word on habitats used by spotted owls.

With these cautions in mind, the general picture that emerges is that owls occurred in habitats ranging from low elevation riparian forests (Bendire 1892, Phillips et al. 1964, and possibly Woodhouse 1853:63) to high elevation coniferous forests, but were most common in high elevation coniferous and mixed coniferous-broadleaved forests, often in canyons. In perhaps the most detailed historical account of the Mexican spotted owl, Ligon (1926:422) described its typical haunts as "deep, narrow, timbered canyons where there are always cool shady places."

Several recent studies describe habitats used by Mexican spotted owls. For example, Kertell (1977), Rinkevich (1991), and Willey (1992) reported on habitats occupied by Mexican spotted owls in southern Utah (Colorado Plateau RU). All reported that owls were typically found in narrow, steep-walled canyons, and all suggested that distribution was restricted by the availability of such canyons. Reynolds (1993) also reported finding owls only in "steep-walled, deeply-cut canyons characterized or dominated by exposed rocky slopes and tiers of rock cliffs" in Colorado (Colorado Plateau and Southern Rocky Mountains-Colorado Recovery Units; see USDI 1995 for discussion of specific Recovery Units [RUs] within the range of the Mexican spotted owl).

Ganey and Balda (1989a) recorded cover type at 55 roost sites in northern Arizona, of which 53 were located in the Upper Gila Mountains RU. Of these, 92.4% were located in mixed-conifer forest. The remaining 7.6% were classified as ponderosa pine, but more likely were in ponderosa pine-Gambel oak forest. Most were located in steep canyons or on montane slopes. Also in this RU, Seamans and Gutiérrez (in press) recorded cover type at 79 roost and 28 nest sites in the Tularosa Mountains, New Mexico. These owls roosted and nested primarily in mixed-conifer forests containing an oak component, usually on the lower third of north-facing slopes (Seamans and Gutiérrez in press: fig. 1).

In the Basin and Range-West RU, Ganey and Balda (1989a) recorded cover type at 64 roost sites. Most were in mixed-conifer (48.4%) or Madrean pine-oak (29.7%) forest, with 14.1% in encinal (evergreen oak), and 7.8% in ponderosa pine forest. At 19 roost and/or nest sites observed by Duncan and Taiz (1992) in this RU, 31.6% were in mixed-conifer forest, 31.6% in Madrean pine-oak forest, 26.3% in Arizona cypress forest, and 10.5% in encinal. In both studies, most owls were observed in montane canyons.

Skaggs and Raitt (1988) surveyed 42,105 ha (104,000 acres) in the Basin and Range-East RU. Survey areas were divided into 18 plots of 23.3-km^2 (9-mi^2) prior to survey, with all plots classified by the dominant forest type within the plot (6 each in mixed-conifer, ponderosa pine, or pinyon-juniper). They found 33 occupied sites; 72.7% in mixed-conifer, 18.2% in ponderosa pine, and 9.1% in pinyon-juniper. Even in plots classified as ponderosa pine or pinyon-juniper, the owls typically roosted in pockets of mixed-conifer forest (Roger Skaggs, New Mexico State Univ., Las Cruces, NM, pers. comm.). Kroel (1991:39) also noted that owls in this RU roosted primarily (79% of observed roosts) in mixed-conifer forest, with limited use of ponderosa pine forest and pinyon-juniper woodland (14 and 4% of all roosts, respectively).

Little recent information exists regarding habitat use by spotted owls in Mexico. However, Tarango et al. (1994) reported finding Mexican spotted owls in isolated patches of pine-oak forest in steep canyons in the Sierra Madre Occidental-Norte.

With regard to all of the above studies, it is important to note that definitions of cover types may have varied slightly among observers, and we cannot be certain that cover types are completely consistent with definitions used in this Plan.

Recovery Team Analysis of Recent Inventory Data

Recent inventories by land management agencies, particularly the U. S. Forest Service (FS), have generated considerable information on owl locations and habitats used. We used this information to evaluate use of vegetation (or cover) types across the range of the subspecies. Crews visited FS District and Supervisors offices, collated inventory and monitoring data from 1990 (when survey efforts were standardized throughout the Region) to 1993 (when these data were collated), and entered the information gathered into a data base. These same crews also collated records from the NPS, BLM, Tribal lands, State wildlife agencies, Fort Huachuca Military Reservation, and independent researchers in both the United States and Mexico for the same time period. Thus, we attempted to gather all existing information on current distribution and habitat use of the Mexican spotted owl across its range.

Vegetation type at nest or roost sites was entered directly from field data forms, with types generally corresponding to Series level designations described in Brown et al. (1980). We could not assess the accuracy or consistency of habitat classification across the range of the owl. All locations for which vegetation type information was missing or ambiguous were omitted from analysis.

We used only visual observations (such as birds at roost and nest sites) to assess habitat use because habitat cannot be determined for distant owls heard at night. Most roost or nest locations entered in this database could not be assigned to a particular "management territory." As a result, we are uncertain how many unique pairs of owls were represented, or how many roost or nest sites might represent a single pair. This potentially serious lack of independence in the data rendered statistical comparisons among RUs or between roost and nest sites meaningless. Therefore, we simply present summaries of vegetation types used for roosting and nesting by Recovery Unit. We could not compare habitat use with habitat occurrence at this scale, because of the problems discussed above regarding lack of independence, because no geographical information system (GIS) coverage was available documenting areas surveyed, and because we were unable to obtain a rangewide vegetation type coverage. The closest we could come to a rangewide vegetation type coverage covered only the U. S. portion of the range of the Mexican spotted owl, and had a minimum resolution of 1 km^2 (Keitt et al. 1995). This scale is not appropriate for evaluating roost and nest sites, which require a much finer scale of resolution.

Mexican spotted owls used a variety of vegetation types across their range (Table 4.1). Although the range of vegetation types used varied among RUs, mixed-conifer forest was heavily used in most RUs. In contrast, encinal was used only in the Basin and Range-West, and pine-oak forest was used primarily in the Basin and Range-West and Sierra Madre Occidental-Norte. The pine-oak forest found in these RUs is Madrean in affinity and differs in both species composition and habitat structure from the ponderosa pine-Gambel oak forest found in other RUs (Brown et al. 1980, Ganey et al. 1992). Ponderosa pine forest was used rarely, and pinyon-juniper woodland was used primarily by owls in the Colorado Plateau. Riparian forest was used in several RUs, but at relatively low levels.

We could not statistically compare RUs because of the problems discussed above. Based on discussions with researchers and managers familiar with local situations, however, we believe that the observed differences in patterns of habitat use among RUs are both real and ecologically important.

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Table 4.1. Percent of nest (top row) and roost (bottom row) sites in various vegetation types in different Recovery Units. Based on analysis of inventory and monitoring data collected since 1990. Vegetation types follow Series in Brown et al. (1980).

		Vegetation Type						
Recovery Unit	N	Evergreen oak	Mixed-conifer	Pinyon-juniper	Pine-oak[1]	Pine[2]	Riparian[3]	Other[4]
Colorado Plateau	8		75.0	25.0				
	22		77.3	18.2			4.5	
S. Rocky Mountains-New Mexico	9		88.9		11.1			
	70		98.6					1.4
Upper Gila Mountains	185		88.6		3.2	1.6	0.5	5.9
	653		86.7		5.2	1.5	0.5	6.1
Basin and Range-West	74		68.9		28.4		2.7	
	165	5.5	49.1	0.6	35.8	1.2	4.8	3.0
Basin and Range-East	70		100.0					
	328		92.1	0.3	0.3	2.4		4.9
Sierra Madre Occidental - Norte	1				100.0			
	17	5.9	29.4		35.3	23.5	5.9	

[1] Includes sites that might better be classified as oak-pine in the Basin and Range-West Recovery Unit and Sierra Madre Occidental - Norte.

[2] Ponderosa pine except in Sierra Madre Occidental - Norte, where a variety of other pine types are represented.

[3] Includes all broadleaved deciduous riparian forest types.

[4] Contains spruce-fir, Arizona cypress, and unknown other vegetation types.

PATTERNS OF HABITAT USE AT THE HOME-RANGE SCALE

Home-Range Size

Several studies have examined home-range size and/or habitat use within home ranges of radio-tagged Mexican spotted owls. Minimum convex polygon (MCP; Mohr 1947) and 95% adaptive kernel (AK; Worton 1989, where possible) estimates of home-range size from these studies are presented in Table 4.2. Estimates are presented separately for each study area. Home-range size appeared to vary considerably among study areas, even within a restricted geographic area (Table 4.2). For example, Zwank et al. (1994) found that home-range size differed significantly between two drainages in the Sacramento Mountains, New Mexico. Ranges were smaller in the Rio Penasco watershed (n = 5 owls), where mixed-conifer forest comprised 65-86% of home ranges, than in the Sixteen Springs watershed (n = 4 owls), where mixed-conifer forest comprised only 6-42% of home ranges, with most of the remainder consisting of ponderosa pine forest and pinyon-juniper woodland (Zwank et al. 1994: table 1). Similarly, Ganey and Balda (1989b) observed large differences in home-range size among owls on the San Francisco Peaks and in Walnut Canyon. Although these areas are separated by only approximately 16 km (10 mi), habitat composition differs between the two areas (Ganey and Balda 1994: table 3). These results suggest that home-range size of Mexican spotted owls may vary among cover types. However, small numbers of owls tracked in all studies, as well as differences in sampling intervals and seasons covered limit our ability to make comparisons among study areas. Consequently, we caution that these numbers represent general estimates of areas used by spotted owls, and as such do not support sweeping generalizations about differences between areas and/or cover types.

Size of Activity Centers

Gutierrez et al. (1992) suggested that the smallest area encompassing 50% of nocturnal foraging locations (the 50% adaptive kernel) could define a foraging activity center. Because of the great variability in available estimates of home-range size for Mexican spotted owls, we took a more conservative approach and defined a nocturnal activity center based on the area enclosed by the adaptive kernel contour encompassing 75% of foraging locations. This activity center was defined only for territories where both pair members were radio-tagged. In general, owls appeared to forage primarily within a relatively small portion of the home range, suggesting high concentration of activity (Table 4.3). This pattern appeared to hold regardless of RU or study area (but see above cautions regarding comparisons among studies).

Habitat Composition and Use

Three studies quantified habitat composition within MCP home ranges of radio-tagged owls (Willey 1993, Ganey and Balda 1994, Zwank et al. 1994). Home ranges were most variable in terms of vegetation types in the Colorado Plateau RU, encompassing types ranging from mixed-conifer forest to mountain shrub and grassland (Willey 1993: table 4). Home ranges were dominated by mixed-conifer and ponderosa pine forests in the Upper Gila Mountains RU (Ganey and Balda 1994), and by mixed-conifer forest, ponderosa pine forest, and pinyon-juniper woodland in the Basin and Range-East RU (Zwank et al. 1994).

Ganey and Balda (1994) compared use of vegetation types by foraging, radio-tagged owls to the area of those types within the MCP home range (a measure of relative availability), using chi-square tests and Bonferroni confidence intervals (Neu et al. 1974, Byers et al. 1984). This comparison involved eight owls representing five pairs on three study areas.

Observed patterns of habitat use by foraging owls were complex. In relation to area of different forest types within their home ranges, all individual owls used forest types nonrandomly. All forest types were used by foraging owls. In general, individual owls foraged significantly more than or as expected in unlogged forests and significantly less than or as expected in selec-

Table 4.2. Home-range sizes (ha) of radio-marked Mexican spotted owls. Part A shows ranges of pairs with both members radio-tagged; part B shows ranges for individual owls. Study areas represent mesic mixed-conifer forest on the San Francisco Peaks (SFP), White Mountains (WM), and Sacramento Mountains (SM-MC); a mixture of mixed-conifer, ponderosa pine, and xeric pinyon-juniper in the Sacramento Mountains (SM-XE); a rocky canyon (Walnut Canyon, WC); ponderosa pine-Gambel oak forest near Bar-M Canyon (BMC); rugged canyons with mixed forests in the San Mateo Mountains (SANMAT); a mixture of mesic mixed-conifer forest and pinyon-juniper in rocky canyons along Elk Ridge (MANTI) and in Zion National Park (ZION); and xeric pinyon-juniper in rocky canyons in Capitol Reef and Canyonlands National Parks (CNP). Shown are the means (± SD) for 100% minimum convex polygon (MCP) and 95% adaptive kernel (95% AK) estimates.

Recovery Unit Study Area	Pair Home Ranges				
	MCP	95% AK	Number of Pairs	Number of Locations	Months Tracked
Upper Gila Mountains					
SFP[1]	1081 ± 70	892 ± 50	2	409 ± 139	11 ± 4
WC[1]	381	283	1	439	14
BMC[2]	1551 ± 505	997 ± 493	7	401 ± 157	20 ± 11
Basin and Range-East					
SM-MC[3]	956 ± 172		2	324 ± 71	9 ± 1
SM-MC[2]	573 ± 25	281 ± 136	2	458 ± 110	12 ± 0
SM-XE[3]	1401 ± 322		2	253 ± 54	7 ± 0
SM-XE[2]	694 ± 98	377 ± 29	2	598 ± 176	12 ± 0

Table 4.2. (continued)

Recovery Unit Study Area	Individual Home Ranges				
	MCP	95% AK	Number of Owls	Number of Locations	Months Tracked
Colorado Plateau					
ZION[4]	924 ± 192	878 ± 220	4	150 ± 48	12 ± 2
CNP[4]	1487 ± 568	16[illegible]7 ± 665	2	175 ± 3	14 ± 0
MANTI[4]	1080 ± 289	1006 ± 144	5	130 ± 45	12 ± 2
Upper Gila Mountains					
SFP[1]	882 ± 194	885 ± 209	4	205 ± 58	8 ± 5
WM[1]	586 ± 176	530 ± 162	2	174 ± 4	12 ± 0
WC[1]	327 ± 60	262 ± 80	2	220 ± 26	12 ± 0
BMC[2]	1053 ± 502	841 ± 407	13	201 ± 81	16 ± 10
SANMAT[5]	261 ± 167		4		<8?
Basin and Range - East					
SM-MC[3]	586 ± 340		5	150 ± 38	8 ± 2
SM-MC[2]	452 ± 137	254 ± 105	5	275 ± 14	12 ± 0
SM-XE[3]	937 ± 391		4	126 ± 29	5 ± 2
SM-XE[2]	901 ± 469	661 ± 484	6	339 ± 41	12 ± 1

[1] Recalculated from Ganey (1988

[2] Ganey and Block, unpublished data

[3] Recalculated from Kroel (1991)

[4] D.W. Willey, unpublished data

[5] Peter Stacey, Univ. of Nevada, Reno, pers. comm.

Table 4.3. Size (mean ± standard deviation) of nocturnal activity centers of radio-tagged pairs of Mexcan spotted owls in the Upper Gila Mountains and Basin and Range-East Recovery units. Activity centers defined as the area included in the adaptive kernel contour enclosing 75% of owl foraging locations.

	Upper Gila Mountains			Basin and Range-East	
	San Francisco Peaks[1]	Walnut Canyon[1]	Bar-M Canyon[2]	Sacramento Mountains-mesic[2]	Sacramento Mountains- xeric[2]
n	2	1	7	2	2
No. of locations	392 ± 132	351	226 ± 94	150 ± 29	165 ± 61
75% contour (ha)	353 ± 139	116	353 ± 182	70 ± 9	174 ± 33

[1] Recalculated from data in Ganey (1988)

[2] Ganey and Block, unpublished data

tively logged forest types (Table 4.4). This comparison is overly simplistic, however. Both logged and unlogged forests contained a wide range of stand structures. Some logged stands were used for foraging, and some unlogged stands were not used. In addition, two of the unlogged forest types (virgin mixed-conifer forest on rocky slopes and ponderosa pine-oak-juniper forest) were found primarily on rocky slopes interspersed with significant rock outcrops and cliffs, and owls appeared to forage in these rocky areas as well as in the forest (Ganey and Balda (1994:165). Thus, these findings do not indicate that all unlogged stands provide suitable foraging conditions and that all logged stands do not. Rather, they suggest that patterns of habitat use by foraging owls are complex and not amenable to simplistic explanations. At this time, we cannot explain why some logged forests are used and others are not.

Differences in patterns of habitat use among and within study areas also suggest that patterns of habitat use for foraging are complex. Use of particular forest types sometimes varied considerably among individual owls within a study area (Table 4.4), and even between members of a mated pair (Ganey and Balda 1994: table 3). In short, there is considerable variability in patterns of habitat use for foraging. As a result, it is difficult to generalize about patterns of habitat selection by foraging owls based on currently-available data.

In contrast to the variable patterns observed among foraging owls, patterns of habitat use by roosting owls were relatively consistent among study areas and individual owls. Habitat use for roosting was not compared statistically to habitat occurrence because of small sample sizes for some individual owls. All owls roosted primarily in unlogged mixed-conifer forests, but some used unlogged ponderosa pine forest as well (Ganey and Balda 1994: table 3). Very little roosting occurred in logged stands, particularly during the breeding season.

Seasonal Movements

Most Mexican spotted owls appear to remain in the same general area throughout the year, whereas others migrate in winter, usually to lower elevations. Year-round residents often use larger ranges during the nonbreeding season than during the breeding season (Kroel 1991, Willey 1993, Ganey and Block unpublished data), and there appear to be shifts in use of area and habitat for some owls (Ganey and Balda 1989b, Kroel 1991, Willey 1993, Ganey and Block unpublished data). No quantitative results are yet available that describe wintering habitats used by owls remaining in the same area throughout the year.

Most samples of Mexican spotted owls studied using radiotelemetry appear to have some individuals who are either migratory or nomadic in winter, but this generally represents a minority of the population. For example, Willey (1993:15) reported that two of 11 (18.2%) radio-tagged owls on the Colorado Plateau RU migrated during winter. Both apparently left the breeding area during October and returned during February. One moved up in elevation to winter in coniferous forest, whereas the other wintered in mountain shrub habitat. Both owls moved 20-25 km between breeding season ranges and winter ranges.

In the Upper Gila Mountains RU, two of eight owls (25%) in one study (Ganey and Balda 1989b) and 2 of 13 (15.4%) in another (Ganey and Block unpublished data) migrated during the winter. All left the breeding-season range between November and January, and returned in March or April. Wintering areas of two owls were never located. The remaining two owls migrated approximately 50 km, from ponderosa pine-Gambel oak forest at approximately 2290 m (7500 ft) in elevation to pinyon-juniper woodland at approximately 1370 m (4490 ft) in elevation (Ganey et al. 1992, Ganey and Block unpublished data). The wintering area was located in the Basin and Range-West RU, providing evidence that some individuals may move seasonally between RUs.

Table 4.4. Use of forest types for foraging by radio-tagged Mexican spotted owls on three study areas in northern Arizona. Data summarized from Ganey and Balda (1994).

Table 4.4.

	Study Areas								
	Walnut Canyon (n=2)			San Francisco Peaks (n=4)			White Mountains (n=2)		
Forest type[1]	>[2]	=	<	>	=	<	>	=	<
Virgin mixed-conifer forest					4		2		
Virgin mixed-conifer forest on rocky slopes	2			1	1	1			
Virgin ponderosa pine forest		2		2	2		2		
Virgin ponderosa pine-oak-juniper forest	2			1	1				
Managed mixed-conifer forest					1	3			2
Managed ponderosa pine forest			2		2	2			2

[1] Forest types described in Ganey and Balda (1994). Not all forest types were found in all home ranges.

[2] >, =, < indicate that owl use of that forest type was either greater than, equal to, or less than expected use, respectively, based on the overall area of that forest type within the home ranges of individual owls. Values shown are numbers of owls in each category.

In the Basin and Range-East RU, neither Zwank et al. (1994, n = 9 owls) nor Ganey and Block (unpublished data, n = 15 owls) observed migration during the nonbreeding season, but two of eight radio-tagged owls (25%) in another study moved during the winter. These owls moved downslope from mixed-conifer forests to the interface between pinyon-juniper woodland and desert scrub (Roger Skaggs, New Mexico State Univ., Las Cruces, NM; pers. comm.).

PATTERNS OF HABITAT USE AT THE STAND SCALE

Limited data were available on habitat use by Mexican spotted owls at the stand scale during preparation of this Recovery Plan. Analysis of FS data for some nesting stands in the Upper Gila Mountains and Basin and Range-East RUs suggests that owls typically nest in relatively dense stands with high basal areas of live trees, a wide range of tree sizes, suggesting an uneven-aged structure (Figure 4.1), and a large tree component (Table 4.5). The data were also used to estimate diminution quotients, or q-factors, for nesting stands in both RUs (Table 4.5). This parameter is useful in uneven-aged management of timber stands. It describes the ratio of number of trees in any diameter class to the number in the next-lowest diameter class, and thus describes the relative shape of the diameter distribution (Daniel et al. 1979). In both RUs, q-factors averaged <1.4.

PATTERNS OF HABITAT USE AT THE SITE SCALE

Several studies have examined characteristics of specific sites used by Mexican spotted owls, such as nest and roost sites. These are discussed below, by site type.

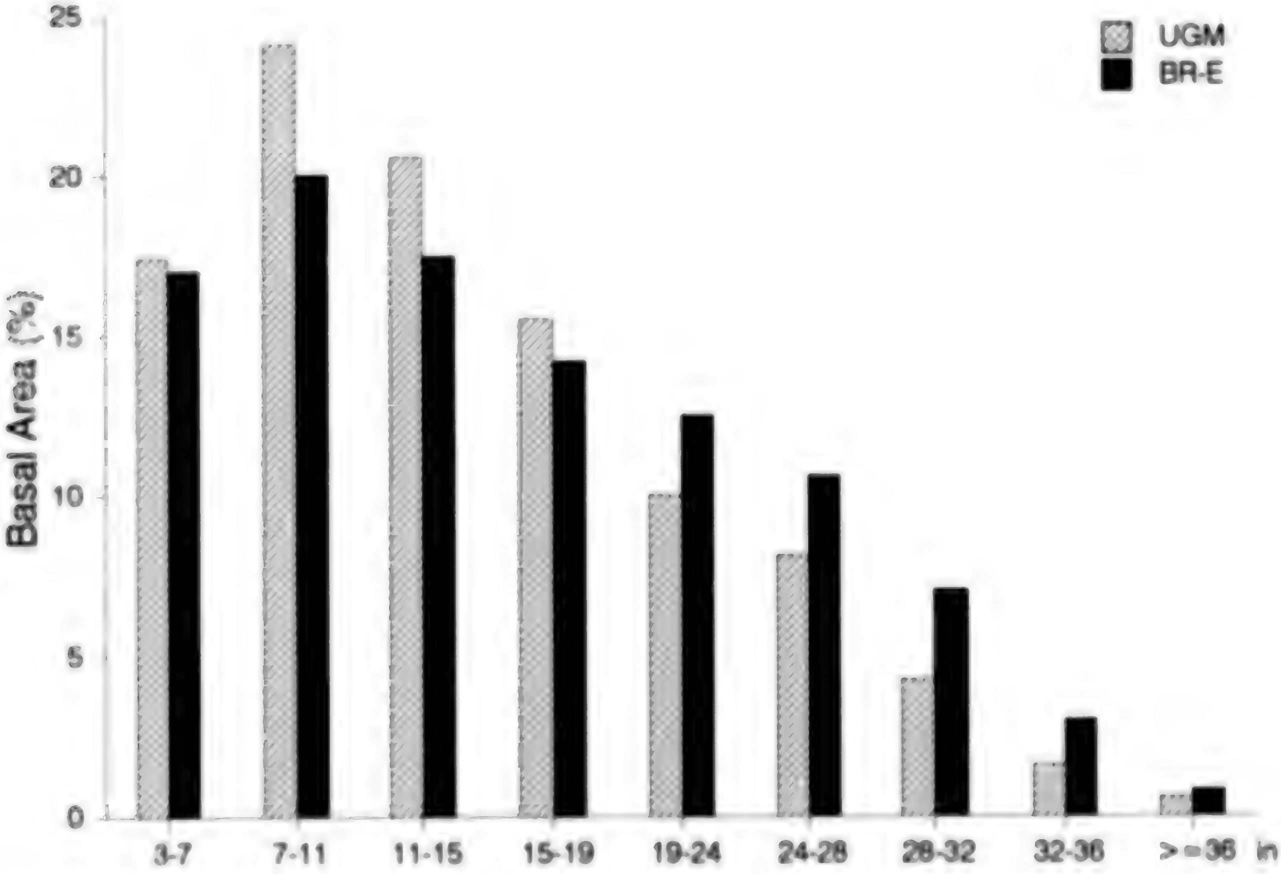

Figure 4.1. Diameter distributions of live trees sampled in nest stands in the Upper Gila Mountains (UGM: n = 13 stands) and the Basin and Range - East (BR-E: n = 44 stands) Recovery Units. Shown is percentage of total live tree basal area by 4 in (10 cm) size classes. Data from the FS stand data base.

Table 4.5. Selected characteristics of nest stands of Mexican spotted owls in the Upper Gila Mountains (n = 13 stands) and Basin and Range-East (n = 44 stands) Recovery Units. Data from the stand data bases for the Apache-Sitgreaves (Upper Gila Mountains) and Lincoln (Basin and Range-East) National Forests. Values shown are means; no estimates of variability among stands were available.

			% of Total Basal Area by Diameter Class				
Recovery Unit	**Live Tree Basal Area (m^2/ha)**	**Trees/ha**	**<30.5 cm**	**30.6-45.5 cm**	**45.6-61 cm**	**>61 cm**	**q factor[1]**
Upper Gila Mountains	28.1	436.5	44	25	17	14	1.33 (0.73)
Basin and Range-East	43.2	668.9	52	26	13	9	1.37 (0.75)

[1] Q factors calculated including all trees ≥ 10 cm (4 in) in diameter at breast height, grouped into 5 cm (2 in) diameter classes. R^2 values for q factor computation shown in parentheses.

Nest Sites

Armstrong et al. (1994) and Arizona Game and Fish Department (unpublished data) sampled habitat characteristics at nest sites on the Apache-Sitgreaves National Forest, Upper Gila Mountains RU (Table 4.6). They sampled both tree and cliff nests, but the majority of nests sampled were in trees. While limited in scope, their results suggest that owls typically nested in large trees in closed-canopy stands.

Ruess (1995) documented current stand structure on 0.04-ha (0.1-ac) plots at 11 nest and 9 roost sites representing an unknown number of owl pairs in ponderosa pine-Gambel oak forest in northcentral Arizona. He also attempted to estimate what these sites would have looked like in terms of forest structure in 1876, before effective fire suppression began in this area, using methods developed by Covington and Moore (1994). With a few exceptions, Ruess (1995) pooled roost and nest sites when presenting data. Thus, both site types will be discussed together here.

Comparisons of current and estimated presettlement conditions on these sites suggest that pronounced increases have occurred in tree density, basal area, and canopy cover. Current density of trees above breast height averaged 1708.8 ± 1009.1 (SD) trees/ha (691.8 ± 408.5 trees/ac), versus an estimated presettlement density of 0-225 trees/ha (0-91 trees/ac; [Ruess 1995:12, no mean presented]). Current basal area averaged 66.7 m^2/ha (290.7 ft^2/ac; [Ruess 1995:12, no estimate of variability provided]), versus an estimated average basal area of 17.8 m^2/ha (77.6 ft^2/ac; [Ruess 1995:12, no estimate of variability provided]) circa 1876. Canopy cover, modeled based on projection of mapped tree crowns, was estimated at 44.8 ± 12.9% at present, versus 2.2 ± 2.9% circa 1876 (Ruess 1995:22). Variability in species composition and structural variables was relatively high for both estimated 1876 conditions and current conditions.

Two detailed treatments of nesting habitat of the Mexican spotted owl are currently available (SWCA 1992, Seamans and Gutiérrez in press). Seamans and Gutiérrez (in press) compared habitat characteristics between 27 plots (0.04 ha; 0.1 ac) centered on nest trees and 27 random plots from throughout their study area (Tularosa Mountains, Gila National Forest, New Mexico; Upper Gila Mountains RU). The nest plots represented nest sites of 27 pairs of owls. Random plots were centered on a randomly-selected tree ≥27.3 cm diameter at breast height (dbh), the minimum diameter among the 27 nest trees. This was an attempt to minimize the potential bias associated with centering nest plots on large trees and random plots on trees of any size.

Owls nested in mixed-conifer/oak forests more than expected by chance, and in pine-oak and pinyon-juniper forests less than expected (Seamans and Gutiérrez in press: fig. 1). Most nests were located on the lower third of slopes, and the mean slope aspect at nest sites was northerly. Nest plots differed significantly from randomly-located plots within the study area for a number of variables (Table 4.7). In a discriminant function analysis, nest plots were best separated from random plots by variance in tree height, canopy closure, and basal area of mature trees (defined as stems >45.8 cm dbh); all were greater on nest than on random plots (Table 4.7). Cross-validation analyses indicated that the results of the discriminant analysis were stable, and the discriminant function successfully classified 84.6% of a sample of 13 owl nest sites from other mountain ranges outside the study area (Seamans and Gutiérrez in press).

Seamans and Gutiérrez (in press) also compared nest plots to 27 plots randomly located within nest stands. Nest plots did not differ significantly from random plots within the same stand.

SWCA (1992) sampled habitat characteristics at 84 nests on FS lands in Arizona and New Mexico. They sampled habitat characteristics within circular plots (0.2 ha; 0.5 ac), each centered on and including either a nest tree, a randomly selected tree within the nest stand, or a randomly selected tree in a stand within 0.8 km (0.5 mi) of the nest. These will be referred to as nest, nest-stand, and random-stand plots. SWCA (1992) concluded that owls selected nest sites based primarily on the availability of a suitable nest tree. Hardwood snag basal area and canopy cover also emerged as potentially impor-

Table 4.6. Habitat characteristics sampled at Mexican spotted owl nest sites on three Ranger districts, Apache-Sitgreaves National Forest, Upper Gila Mountains Recovery Unit. Shown are means and standard errors (in parentheses). Nests sampled were found in trees (n = 30) or on cliffs (n = 4); some variables are relevant to only one of the two situations.

	Ranger District					
Variable	**Alpine (n=16)**[1]		**Chevelon (n=12)**[2]		**Heber (n=6)**[2]	
Elevation (m)	2,397	(59)	2,095	(30)	2,154	(34)
Slope (%)	51.2	(5.2)	50.4	(7.5)	37.2	(5.1)
Nest tree dbh (cm)	62.0	(6.1)	59.4	(5.1)	63.2	(12.2)
Nest tree height (m)	32.3	(2.4)	30.3	(1.4)	26.8	(4.9)
Cliff height (m)	20.3	(2.8)				
Nest height in tree (m)	16.1	(1.2)	18.3	(1.6)	14.3	(2.8)
Nest height on cliff (m)	15.8	(3.8)	7.9			
Basal area (m^2/ha)	27.8	(2.4)				
Canopy cover at nest (%)	96	(0.7)	88	(1.7)	82.5	(16.5)

[1] Armstrong et al. (1994; n = 13 tree and 3 cliff nests)

[2] Arizona Game and Fish Department (unpublished data; n = 11 tree and 1 cliff nest on Chevelon Ranger District, 6 tree nests on Heber Ranger District).

Table 4.7. Habitat characteristics at Mexican spotted owl nest (n = 27) and randomly located sites (n = 27) in the Tularosa Mountains, New Mexico; Upper Gila Mountains RU. Shown are means and standard deviation (in parentheses). Data from Seamans and Gutiérrez (in press).

	Site Type			
Variable	**Nest**		**Random**	
Canopy closure (%)	75.9	(14.1)	56.3	(20.4)
Tree height (m)	20.4	(5.8)	13.9	(5.7)
Tree height variance	2.2	(1.0)	1.1	(1.0)
Live tree basal area (m^2/ha)	25.3	(13.2)	18.9	(10.8)
Basal area of trees ≥45.58 cm dbh (m^2/ha)	12.4	(10.5)	4.3	(6.0)

tant factors in their analysis. This data set was reanalyzed by both Zhou (1994) and the Team, using different methods. These reanalyses are discussed below.

Reanalysis of SWCA (1992) by Zhou (1994)

Zhou (1994) conducted three, two-group linear discriminant function analyses between nest, nest-stand, and random-stand plots. He concluded (Zhou 1994:96-102) that:

1. Mexican spotted owl nest stands differed from randomly-selected stands in the vicinity. Nest stands typically had a wide range of tree diameters and heights, large maximum tree diameter, and high tree basal area. Nest stands also had higher species richness than random stands.

2. Mexican spotted owls also selected for microsites within nest stands. Nest plots were located on steeper slopes, had greater live tree basal area, and were more likely to be found on north or east aspects than nest-stand plots.

3. Diameter and height distributions had similar shapes on all three plot types, but the spread of the distribution differed among plot types. With respect to diameter distributions, the nest and nest-stand plots had greater percentages of large trees. With respect to tree height, nest and nest-stand plots had greater spread to the distribution than random-stand plots. This wider spread suggests a tendency for the owl to nest in multi-storied stands, as wider spread to the height distribution increases the probability that the stand is multi-storied.

4. Mexican spotted owls nested in large trees. The mean nest tree was located in the 92nd diameter percentile and the 79th height percentile.

5. The linear combination of habitat variables was more successful in classifying habitat than reliance on interpretation of coefficients for single variables.

Reanalysis of SWCA (1992) by the Recovery Team

The Team also reanalyzed the data from SWCA (1992). The Team was interested in patterns of habitat use within particular geographic regions, and in how similar nest sites were among regions. This reanalysis was restricted to sites in the Upper Gila Mountains and Basin and Range-East RUs because these were the only RUs well represented among nests sampled ($n = 44$ and 26 sites, respectively). Because sample sizes were small, sites were pooled among habitat types within each RU. Habitat characteristics were first compared among plot types within RUs, to see if nest sites differed from nest stands or locally-available, randomly-selected stands. Characteristics of nest plots were next compared between RUs, to see how similar nesting habitat was in different geographic areas.

We used chi-square tests to evaluate differences in tree species composition between plot types (and/or RUs), and Kolmogorov-Smirnov tests to compare diameter distributions. Because the Kolmogorov-Smirnov test compares only two groups at a time, three separate tests were necessary to compare all three plot types. To avoid inflating the Type I error rate, we partitioned the error among these three comparisons using a Bonferroni adjustment, and used an alpha level of $P < 0.016$ for significance.

Other habitat variables were compared among plots or between RUs using univariate ANOVAs. Where these comparisons were significant, Scheffe's multiple range test was used to determine where the differences occurred. Variables included diameter at breast height (dbh) of center tree, density (trees/ha) of live trees and snags >12 cm (4.7 in) dbh, basal area (m^2/ha) of live trees and snags >12 cm dbh, and volume of logs (m^3/ha) >12 cm in large-end-diameter. Basal area was calculated for each individual tree or snag based on dbh, then summed within each plot. Log volume was calculated using diameter and length measures, assuming a cylindrical shape. Log volumes are overestimated (perhaps greatly) because diameter was measured at the large end.

Comparisons Within Recovery Units.—Tree species composition differed significantly among plot types in both RUs. In the Upper Gila Mountains RU, nest plots contained greater proportions of Douglas-fir and Gambel oak and less ponderosa pine than did random-stand plots (Figure 4.2). In the Basin and Range-East RU, nest and nest-stand plots contained more white fir and less ponderosa pine than did random-stand plots (Figure 4.2).

Diameter distributions in both RUs were significantly different between nest plots and both nest-stand and random-stand plots, but were not significantly different between nest-stand and random-stand plots. Nest plots typically had lower proportions of basal area in the smallest size classes than did random-stand plots (Figure 4.3). In general, basal area was more evenly distributed across size classes in nest stands than in random stands, suggesting a trend toward uneven-aged stands. This trend was more evident in the Basin and Range-East RU than in the Upper Gila Mountains RU. Grouping of trees into four diameter classes, representing "young," "mid-aged," "mature," and "old" trees (USDA Forest Service 1993), also indicates that nest plots contained relatively fewer trees in the smallest size class and more trees in the largest two size classes than other plots (Table 4.8a, b; note that these comparisons refer to percentages of total trees, not to absolute numbers). In both RUs, nest trees were significantly larger ($P < 0.0001$) than randomly-selected trees (Table 4.8). Only 2.4% of 21,951 trees and snags sampled had a dbh ≥ 61.4 cm (24.2 in), the mean diameter for nest trees.

In the Upper Gila Mountains RU, plot types differed significantly in snag density ($P < 0.0001$), snag basal area ($P = 0.0003$), live tree basal area ($P < 0.0001$), and log volume ($P = 0.0006$), but not in live tree density ($P = 0.30$). For snag density, nest plots differed from both nest-stand and random-stand plots; and nest-stand plots also differed from random-stand plots. For snag basal area, nest plots and nest-stand plots differed from random-stand plots, but not from each other. For live tree basal area, nest plots differed from both nest-stand and random-stand plots, but we found no difference between the latter two plot types. For

Figure 4.2a. Tree species composition within nest- and random-stand plots. Data reanalyzed from SWCA (1992). Upper Gila Mountains Recovery Unit (n = 44 sites).

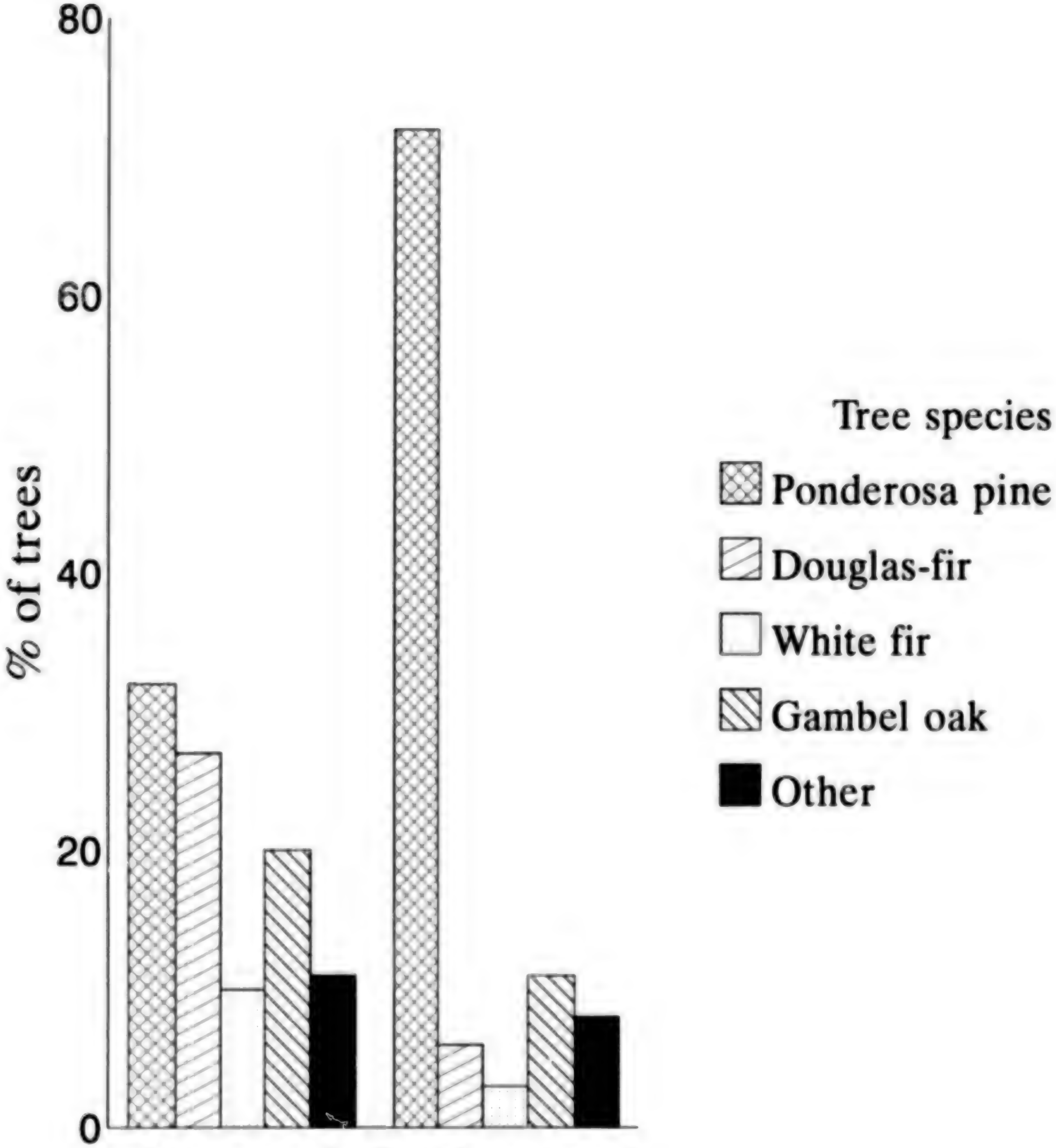

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Figure 4.2b. Basin and Range-East Recovery Unit (n = 26 sites).

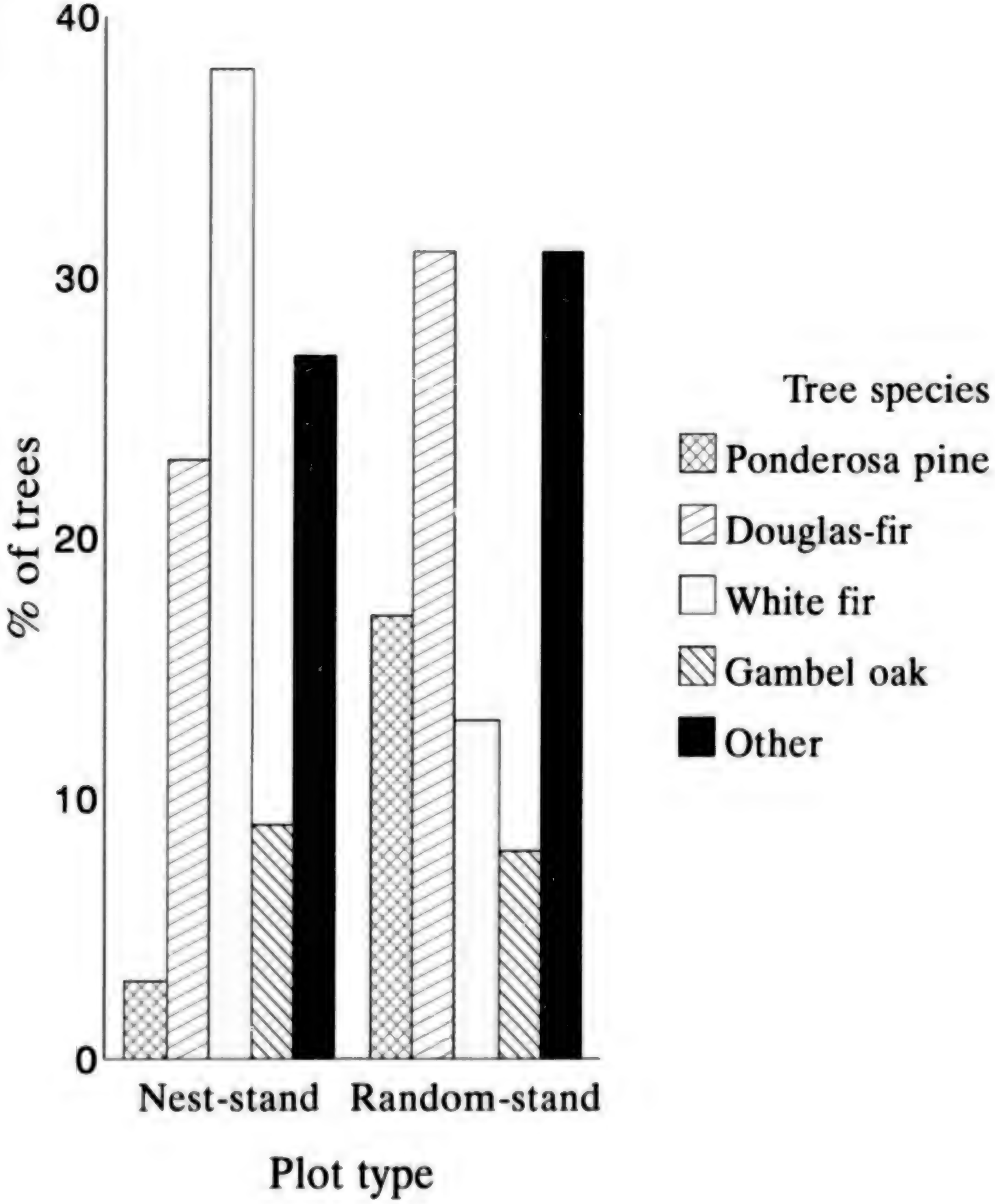

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Figure 4.3. Diameter distributions of live trees sampled on nest, nest stand, and random stand plots. Shown is percentage of total live tree basal area by 4 in (10 cm) size classes for (**a**) Upper Gila Mountains, and (**b**) Basin and Range-East. Data reanalyzed from SWCA (1992).

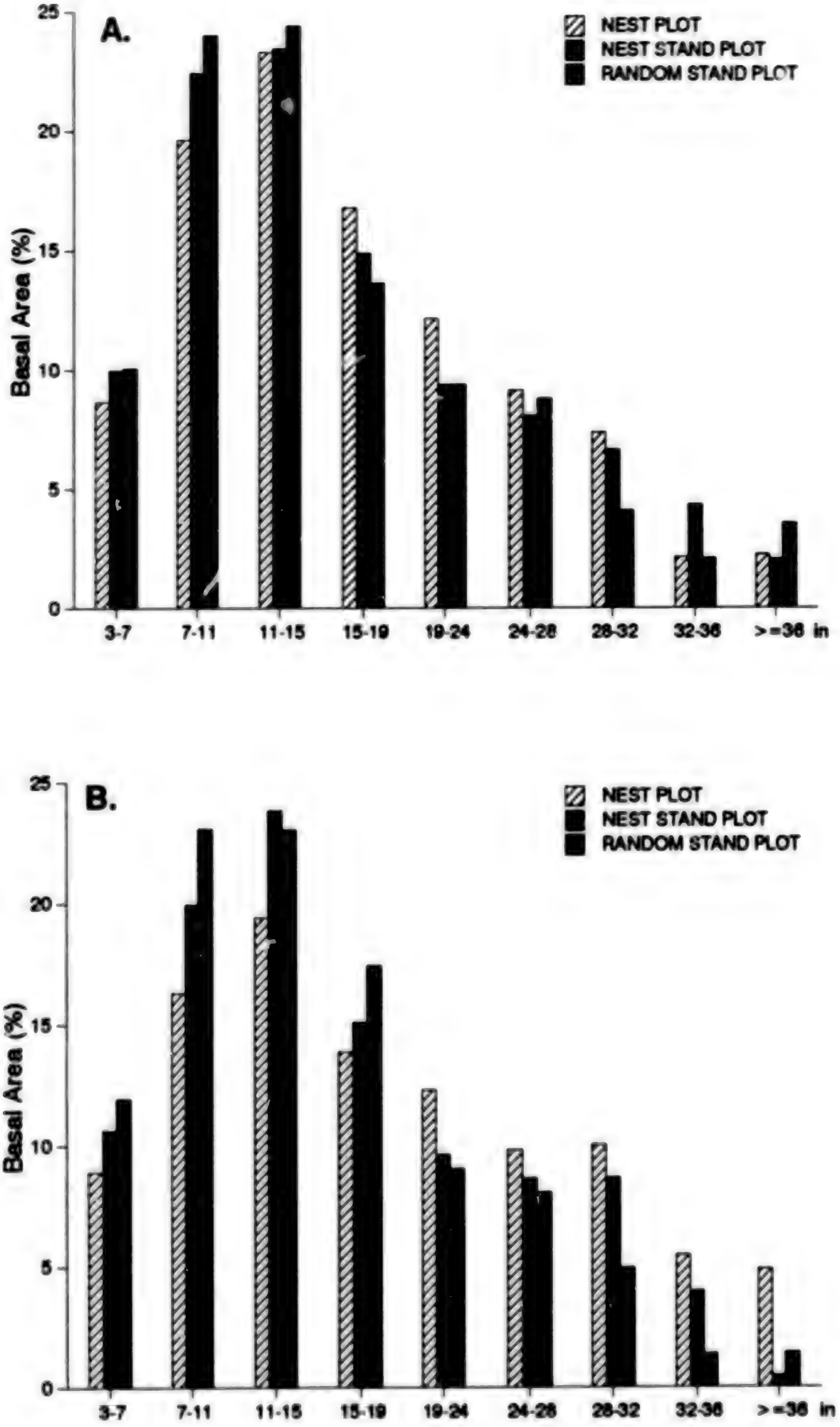

Table 4.8a. Habitat characteristics sampled at 44 Mexican spotted owl nest sites in the Upper Gila Mountains Recovery Unit, as well as at randomly located plots within the nest stand and in a randomly selected stand within 0.5 mi of the nest site. Data reanalyzed from SWCA (1992). Values shown are mean (± standard deviation).

	Plot Type		
Variable	**Nest Plot**	**Nest-stand Plot**	**Random-stand Plot**
Center tree dbh (cm)	60.6[a] (25.6)	32.2[b] (16.9)	32.7[b] (10.2)
Log volume (m^3/ha)	97.8[a] (58.6)	94.7[a] (64.7)	54.6[b] (45.6)
Canopy closure (%)	90.8 (9.0)	87.4 (12.2)	68.4 (18.2)
Trees/ha (> 12 cm dbh)	445.2[a] (175.4)	447.2[a] (209.8)	360.8[a] (200.9)
Snags/ha (> 12 cm dbh)	63.9[a] (40.5)	44.0[b] (30.4)	17.6[c] (21.2)
Live tree basal area (m^2/ha)	30.0[a] (10.4)	24.7[b] (10.6)	20.0[b] (8.4)
Snag basal area (m^2/ha)	4.1[a] (3.4)	3.2[a] (2.8)	1.6[b] (2.1)
Trees < 30.5 cm dbh (%)	72.9	76.8	77.8
Trees 30.5-46 cm dbh (%)	17.7	16.5	15.9
Trees 46-61 cm dbh (%)	5.9	4.1	4.3
Trees >61 cm dbh (%)	3.5	2.6	1.9

[a,b,c] Plot values followed by the same letter do not differ significantly. Canopy closure not tested, reported for informational purposes only.

log volume, both nest plots and nest-stand plots differed from random-stand plots, but not from each other (Table 4.8a).

Of the five characteristics discussed above, only live tree basal area and log volume differed significantly ($P = 0.0121$ and 0.0061, respectively) between plot types in the Basin and Range-East RU (all other P values >0.05). Both variables differed only between nest plots and random-stand plots, not between nest plots and nest-stand plots or between nest-stand and random-stand plots (Table 4.8b).

Comparisons Between Recovery Units.—Species composition of nest sites differed significantly between RUs ($X^2 = 1669$, df = 4, $P < 0.00001$). Nest sites in the Basin and Range-East RU were dominated by white fir and Douglas-fir, those in the Upper Gila Mountains RU by ponderosa pine, Douglas-fir, and Gambel oak (Figure 4.2). Diameter distributions also differed between RUs in comparisons of nest plots (Figure 4.3). No differences were found between RUs for nest tree dbh, live tree basal area or density, snag basal area or density, or log volume.

Table 4.8b. Habitat characteristics sampled at 26 Mexican spotted owl nest sites in the Basin and Range-East Recovery Unit, as well as at randomly located plots within the nest stand and in a randomly selected stand within 0.5 mi of the nest site. Data reanalyzed from SWCA (1992). Values shown are mean (± standard deviation).

	Plot Type		
Variable	**Nest Plot**	**Nest-stand Plot**	**Random-stand Plot**
Center tree dbh (cm)	62.3^{a} (27.8)	28.1^{b} (15.4)	34.4^{b} (15.5)
Log volume (m^3/ha)	120.3^{a} (97.0)	$78.7^{a,b}$ (40.9)	58.9^{b} (54.1)
Canopy closure (%)	89.1 (12.6)	90.0 (9.2)	77.9 (20.8)
Trees/ha (> 12 cm dbh)	400.3^{a} (147.6)	507.0^{a} (177.3)	424.0^{a} (197.4)
Snags/ha (> 12 cm dbh)	55.0^{a} (34.3)	51.5^{a} (38.9)	47.6^{a} (43.1)
Live tree basal area (m^2/ha)	29.4^{a} (12.3)	$28.5^{a,b}$ (8.8)	21.3^{b} (10.1)
Snag basal area (m^2/ha)	4.4^{a} (4.0)	2.4^{a} (2.5)	2.8^{a} (3.2)
Trees < 30.5 cm dbh (%)	72.9	75.8	77.7
Trees 30.5-46 cm dbh (%)	16.3	17.3	16.0
Trees 46-61 cm dbh (%)	6.2	4.2	4.6
Trees > 61 cm dbh (%)	4.6	2.8	1.8

^{a,b,c} Plot values followed by the same letter do not differ significantly. Canopy closure not tested, reported for informational purposes only.

Roost sites

Many studies have described characteristics of roost sites. Some of these descriptions are based on plot-level sampling, whereas others are based on sampling of microsites (such as an individual tree). Microsite descriptions will be discussed under "Patterns of Habitat Use at the Tree scale"; plot-level data are discussed below.

In most of the studies described here, the number of plots measured exceeded the number of owls studied. Thus, these plots cannot be considered totally independent samples, and apparent levels of significance may be inflated (Hurlbert 1984). In most cases, significance levels are so high that we believe pseudoreplication is not a major problem. This is further suggested by the fact that results are comparable between these studies and another (Seamans and Gutiérrez in press) that did not involve pseudoreplication (see below).

Rinkevich (1991; see also Rinkevich and Gutiérrez in review) and Willey (1993) sampled habitat characteristics within roost-centered circular plots of 0.04 ha (0.1 ac) each within the Colorado Plateau RU. All roost sites were located in narrow gorges and/or canyons. Rinkevich (1991) used discriminant function analysis to compare owl roost sites to randomly located sites in Zion National Park, Utah. Owl sites had higher absolute humidity, more vegetation strata, narrower canyon width, and higher percent ground litter than random sites (Rinkevich and Gutiérrez in review). She also compared randomly located plots (n = 54) within canyons where owls were heard to plots (n = 44) within canyons where owls were not heard. Canyons occupied by owls had higher humidity and snag basal area than canyons where owls were not heard (Rinkevich and Gutiérrez in review). The number of plots in these analyses is greater than the number of owls (or canyons in the second analysis), which is unknown.

Willey (1993) sampled habitat characteristics on 129 plots representing roost sites of 14 radio-tagged owls on three study areas in southern Utah. Habitat features at roost sites were compared to characteristics measured at 30-50 random points scattered within each home range (Willey 1993:10). Seven variables were analyzed using discriminant function analysis (Willey 1993:10). Temperature, slope, vegetation canopy cover, and number of ledges and fir trees discriminated between roosting plots and random plots (Willey 1993: table 5). Univariate analyses provided similar results, suggesting that "owls used narrow canyon roosts characterized by cool daytime temperatures, steep slopes, and relatively dense overhead cover. Roosts typically possessed large trees in juxtaposition with caves and ledges, providing a more complex habitat architecture than the surrounding habitat" (Willey 1993:16). The number of plots also exceeded the number of owls in this study.

Ganey (1988, see also Ganey and Balda 1994) sampled habitat characteristics on 157 circular plots (0.04 ha; 0.1 ac) within four owl home ranges (defined using the MCP method) in the Upper Gila Mountains RU. Plots represented high-use roosting and foraging sites, and randomly-selected sites within owl ranges. This study also had more plots than owls. In addition, roost plots were always tree-centered, whereas only some foraging and randomly-selected plots were tree-centered. This could create a positive bias for tree-related variables, such as tree density, tree basal area, and canopy cover, on roost plots.

Plot type was misclassified 33% of the time in a 3-group discriminant function analysis (Ganey 1988; all classification rates refer to jackknifed classification). Most misclassification occurred between foraging and roosting sites. Two-group analyses had higher rates of successful classification and were easier to interpret. The function that resulted in maximum separation of roosting and foraging sites correctly classified 76% of the sites. Variables entering the equation were canopy closure and snags/ha; both were greater on roosting sites (Table 4.9). A comparison of foraging and random sites resulted in 84% successful classification. Variables entering the discriminant function were total basal area and big down logs/ha (defined as logs >30.5 cm [12.0 in] in diameter); both were greater on foraging sites. Comparing roosting and random sites, 90% of all sites were successfully classified. Variables entering the discriminant function were total basal area, snags/ha, canopy closure, and big down logs/ha; all were greater on roosting sites.

Using data from the plots sampled by Ganey (1988), the Team conducted Kolmogorov-Smirnov tests on diameter distributions as described under nest sites (see above). We found no difference in diameter distributions between roosting sites and either foraging or random sites. Diameter distributions were significantly different between foraging and random sites. In general, foraging sites had fewer small trees and more trees in the largest size classes than random sites (Table 4.9). Again, note that these are relative comparisons, and refer to percentages of total trees rather than to absolute numbers of trees.

Seamans and Gutiérrez (in press) compared habitat characteristics sampled on 0.04-ha (0.1-ac) circular plots at 78 roost sites and 71 random sites, Tularosa Mountains, Upper Gila Mountains RU. Roost plots were centered on the roost tree (one plot each from 78 separate owls), and random plots were centered on randomly-selected trees throughout the study area. Owls roosted in mixed-conifer/oak forest more than expected by chance, and in pine-oak forest and

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Table 4.9. Habitat characteristics sampled on 0.04 ha (0.1 ac) circular plots within home ranges of radio-tagged Mexican spotted owls inhabiting mixed-conifer and ponderosa pine forests, northern Arizona (Upper Gila Mountains Recovery Unit). Data from Ganey and Balda (1994); n = six owls occupying four home ranges. Shown are means and standard deviations (in parentheses).

	Plot Type					
Variable	Foraging (n=66)		Roosting (n=33)		Random (n=68)	
Small down logs/ha (< 30.5 cm diam)	116.8	(97.0)	148.2	(95.7)	96.3	(86.1)
Big down logs/ha (> 30.5 cm diam)	83.5	(57.9)	122.8	(66.1)	47.9	(46.3)
Canopy closure (%)	67.2	(10.9)	79.1	(5.2)	51.7	(18.8)
Trees/ha (> 10 cm dbh)	646.7	(288.0)	812.9	(334.3)	445.3	(277.0)
Snags/ha (> 10 cm dbh)	55.0	(48.2)	97.3	(66.8)	22.5	(30.1)
Tree basal area (m^2/ha)	47.5	(13.5)	52.3	(16.4)	29.9	(14.0)
Snag basal area (m^2/ha)	6.4	(7.1)	8.9	(8.2)	2.4	(3.7)
Trees < 30.5 cm dbh (%)	69.1		71.5		73.6	
Trees 30.5 - 46 cm dbh (%)	16.7		18.2		14.7	
Trees 46 - 61 cm dbh (%)	9.2		6.9		6.9	
Trees ≥61 cm dbh (%)	4.9		3.3		4.8	

Table 4.10. Habitat characteristics at Mexican spotted owl roost (n = 78) and random sites in the Tularosa Mountains, New Mexico; Upper Gila Mountains RU. Shown are means and standard deviations (in parenthesis). Data from Seamans and Gutiérrez (in press).

	Site Type			
Variable	**Roost**		**Random**	
Canopy closure (%)	85.2	(9.9)	50.6	(22.4)
Tree height (m)	19.0	(4.3)	11.9	(5.4)
Tree height variance	2.2	(1.4)	1.1	(1.0)
Live tree basal area (m^2/ha)	31.7	(14.2)	19.8	(11.8)
Basal area of trees ≥45.8 cm dbh (m^2/ha)	9.0	(7.9)	3.7	(5.6)

pinyon-juniper woodland less than expected. Most roosts were located on the lower third on slopes. Roost sites differed significantly from random plots for several variables (Table 4.10). Roost sites were best separated from random sites in a discriminant function analysis by canopy closure and height variance; both were greater on roost than on random sites. Cross-validation analyses indicated that the discriminant analysis results were stable (Seamans and Gutiérrez in press).

A. Hodgson and P. Stacey also evaluated roost sites in the Upper Gila Mountains RU (Peter Stacey, Univ. of Nevada, Reno, NV; pers. comm.). They compared habitat characteristics sampled on 0.04-ha (0.1-ac) circular plots between 55 roost sites and 69 random sites in the San Mateo Mountains, New Mexico (the number of plots is also greater than the number of owls in this study). Owls typically roosted in or near canyon bottoms, in relatively dense stands of mixed-conifer forest containing significantly more Douglas-fir, Gambel oak, and limber pine than random sites. Deciduous trees accounted for >28% of total basal area and >50% of total tree density. Roost trees averaged 31 cm (11.6 in) dbh, with most roosting occurring in Douglas-fir (54%) or Gambel oak (21%).

In a second comparison, Hodgson and Stacey restricted their analysis to roost and random sites in mixed-conifer forest (n = 55 and 36, respectively). Within this forest type, roost sites contained greater densities and basal areas of Gambel oak and lower densities and basal areas of conifers than random sites. Differences between roost and random sites were generally greatest with respect to trees from 15-30 cm (5.9-11.8 in) dbh. Roost sites had greater densities of deciduous trees and lower densities of coniferous tree in this size-class than random plots within mixed-conifer forest (Peter Stacey, Univ. of Nevada, Reno, NV; pers. comm.).

Tarango et al. (1994) sampled seven roost sites in Chihuahua, Mexico (Sierra Madre Occidental-Norte RU), using 0.04-ha (0.1-ac) circular plots. Roosts were typically located in multi-layered pine-oak forests on the lower portions of north-facing slopes. Oaks dominated most roost sites by density, comprising 46.6% of the trees present, on average (Tarango et al. 1994:1).

Foraging Sites

The only available data on foraging sites come from Ganey (1988) and Ganey and Balda (1994), discussed above. Relative to random sites, foraging sites within owl home ranges had greater total basal areas and more big down logs/ha (Table 4.9). Relative to roosting sites, foraging sites had lower canopy closure and fewer snags/ha (Table 4.9). In a discriminant function analysis, foraging sites were not as readily distinguished from random sites as roosting sites and were also more variable along a discriminant function axis (Ganey 1988, fig. 12). Both of these results suggest greater variability in foraging habitat than in roosting habitat, consistent with results at the home-range scale (Ganey and Balda 1994). As noted above for roosting sites, foraging sites sampled in this study represented intensively used habitat and probably do not represent the full range of conditions used for foraging.

PATTERNS OF HABITAT USE AT A TREE SCALE

Several studies have examined characteristics of trees and other microsites, such as cliff ledges or caves, used by owls for nesting or roosting. This information is primarily descriptive, and with the exception of SWCA (1992), Ruess (1995), and Seamans and Gutiérrez (in press) provides no basis for comparing used and available trees.

Nest Trees

Nest trees were described, with varying levels of detail, by SWCA (1992), Armstrong et al. (1994), Fletcher and Hollis (1994), Ruess (1995), Seamans and Gutiérrez (in press), and Arizona Game and Fish Department (unpublished data). All of these studies were conducted on FS lands in Arizona and New Mexico, and some nests may be represented in ≥2 studies.

SWCA (1992) sampled 84 nest trees; 81% were conifers and 19% were hardwoods. Fifty percent of all nests were in Douglas-fir trees, with 20% and 19% occurring in Gambel oak and white fir, respectively (SWCA 1992:17). Eight percent (n = 7) of all nests occurred in snags; five of these (57%) were Gambel oak snags (SWCA 1992:17).

Nest trees averaged 63.3 cm (24.9 in) dbh, and ranged from 17-127 cm (6.7-50.0 in; SWCA 1992). Nest structures in living oak trees (n = 14, 17%) were located either in a broken top (n = 3) or a side cavity (n = 11). Nest structures in live conifers included broken top cavities (n = 5), old raptor nests (n = 14), witches brooms (n = 25), stick platforms on "bayonet limbs" (n = 12), stick nests in a multiple-topped tree (n = 4), and a squirrel nest (n = 1). All snag nests were either broken top (n = 5), or cavity (n = 3), and one snag contained both nest types (SWCA 1992:21).

Nest trees were significantly more likely to have a deformed crown than randomly-selected trees (SWCA 1992:30), although 65% of all nest trees had a normal crown form. Types of deformed crown included broken top (19%), multiple top (5%), dead top (10%), and dying top (1%). These percentages are based on 81 nest trees, with three unaccounted for (SWCA 1992: table 9).

Fletcher and Hollis (1994) reported on microsite characteristics of 248 nests located during FS inventory and monitoring activities throughout Arizona and New Mexico. It is impossible to tell how many different pairs of owls these nests represent, and some of these sites may also be included in samples discussed elsewhere (SWCA 1992, Ruess 1995, Seamans and Gutiérrez in press). Furthermore, not all nests could be assigned to a particular Recovery Unit, limiting regional analyses. Therefore, we simply summarize some general patterns resulting from this data set. In many cases, the numbers presented here were recalculated from summary data in Fletcher and Hollis (1994). In those cases the page or figure number where the data were found is cited. Sample sizes vary among values reported, because not all variables were sampled at each site.

Of the 248 nests sampled, 90.3 and 9.7% were in trees and cliffs, respectively (Fletcher and Hollis 1994: fig. 28). Most nests fell within a fairly narrow elevational band, with 72% falling between 1982 and 2287 m (6500-7500 ft), 85.4% falling between 1982 and 2591 m (6500-8500 ft), and 95.5% falling between 1829 and 2591 m (6000-8500 ft), respectively (Fletcher and Hollis 1994: fig. 29). Forty-three percent of the cliff nests were found below 1982 m (6500 ft).

Almost 50% of 236 nests where aspect was recorded were located on north or northeast aspects (Fletcher and Hollis 1994:48). Slope averaged 44 ± 40 (SD)%, with 34.5% of all nests found on slopes >40% (Fletcher and Hollis 1994:49). Almost half of all nests were located

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on the lower third of slopes, with the remainder split almost evenly between middle and upper slopes (Fletcher and Hollis 1994: fig. 50). Roughly 50% of the nests on upper slopes were cliff nests or nests in Gambel oak (Fletcher and Hollis 1994: fig. 50).

Dominant cover types recorded at 237 nest sites were: 80.2% mixed-conifer, 15.2% pine-oak, 2.1% ponderosa pine, 1.7% riparian, and 0.8% other (Fletcher and Hollis 1994: fig. 35). Of 224 tree nests, 57% were in Douglas-fir, 16% in Gambel oak, 13% in white fir, 9% in ponderosa pine, and 5% in other species (Fletcher and Hollis 1994: fig 40).

Nest tree diameter was recorded at 204 nest sites. Trees ≤ 15.2 cm (<6 in) in dbh accounted for 2% of all nests. Relative frequencies of the other size classes were: 13.7% in trees from 15.2-30.5 cm (6-12 in) dbh, 22.6% in trees from 30.5-45.7 cm (12-18 in) dbh, 19.1% in trees from 45.7-61 cm (18-24 in) dbh, and 42.7% in trees >61 cm (>24 in) dbh (Fletcher and Hollis 1994: fig. 41). Forty-five percent of tree nests were classified as "witches broom", with 31.3% in cavities (including broken tops), 14.7% in "debris platforms", and 8.9% in "other stick nests" (Fletcher and Hollis 1994: fig. 36).

Six of 11 nests (54.5%) sampled by Ruess (1995: fig 7) were in Gambel oak, with the remainder in ponderosa pine. Ruess (1995) did not report mean diameters for nest trees, but found four nests (36.4%) in trees of presettlement origin (>115 yrs in age) despite the fact that such trees accounted for only 0.5% of total trees on his study area (Ruess 1995: table 3, fig. 7).

Seamans and Gutiérrez (in press) reported 78% of 27 nests in Douglas-fir, 11% in white fir, 7% in ponderosa pine, and 4% in southwestern white pine. With respect to nest structure, 61% were located in dwarf mistletoe infections, 10.5% in old squirrel nests, 10.5% in old raptor nests, 7% in debris collections, 7% in tree cavities, and one nest (4%, n = 28 nests for these calculations) was on a cliff. Nest trees averaged 60.6 ± 22.4 cm (23.9 ± 17.6 in) in dbh and 164 ± 44.8 years in age. Nest trees were significantly larger and older than randomly sampled trees within the nest vicinity (Seamans and Gutiérrez in press).

Roost Trees

Several researchers have described characteristics of roost trees and a very small area around them. Results are summarized by study area and RU, where possible, in Table 4.11. In general, roost characteristics appeared to be relatively variable among study areas (Table 4.11), suggesting that greater variability exists among roost trees than among trees used for nesting. Canopy closure was more consistent among study areas than most other characteristics sampled, and was relatively high on most study areas. Canopy closure was <65% on only one study area (Canyonlands, Colorado Plateau RU; Table 4.11a). This may reflect the fact that >85% of the roost sites sampled on that study area were located on cliffs or in pinyon-juniper woodland (Table 4.11a).

Roost tree characteristics appeared to be relatively similar among similar habitat types. For example, mean roost tree diameter was more consistent among the mesic mixed-conifer sites (San Francisco Peaks, White Mountains, and Sacramento Mountains: mixed-conifer) than between these sites and other areas. Similarly, characteristics were more similar among the more xeric sites (Sacramento Mountains: xeric mixed forest and Bar-M watershed) than between these and other areas (Table 4.11). One clear pattern that emerges from these studies is that owls roost in smaller trees, on average, than those used for nesting. Ruess (1995: fig. 7), however, noted that three of nine roosts observed in ponderosa pine-Gambel oak forest were >115 yrs old, despite the fact that only 0.5% of all trees sampled in the area were of such age (Ruess 1995: Table 3). This suggests that old, large trees may also be important for roosting in some areas.

Fletcher and Hollis (1994) reported summary characteristics sampled at 433 roost sites located during FS inventory and monitoring efforts in Arizona and New Mexico. This sample is discussed separately here because roost sites could not generally be assigned to particular RUs, as was done for the data sets summarized in Table 4.11. This data set is subject to all the

Table 4.11a. Selected characteristics of roost sites used by radio-tagged Mexican spotted owls in the Colorado Plateau Recovery Unit. Values shown are means (± standard deviation) for continuous variables, % for categorical variables. Source: D.W. Willey (unpublished data).

	Study Area		
Variable	Canyonlands (n=12 owls, 37 roosts)	Manti LaSal (n=12 owls, 35 roosts)	Zion Natl Park (n=18 owls, 57 roosts)
Elevation (m)	1,644 (114)	2,070 (181)	1,820 (180)
Roost tree dbh (cm)	28 (9)	43 (12)	32 (9)
Roost tree height (m)	7 (3)	21 (11)	12 (8)
Canopy closure (%)	45 (5)	72 (3)	65 (3)
Aspect			
E	8.1	31.4	21.1
S	46.0	22.9	28.1
W	8.1	11.4	19.3
N	37.8	34.3	31.6
Cover type			
Mixed-conifer	5.4	91.4	79.0
Ponderosa pine			7.0
Mixed-broadleaf	8.1		
Pinyon-juniper	67.6	8.6	1.7
Slickrock	18.9		12.3
Perch type			
Tree	62.2	65.7	64.9
Snag	2.7	2.9	7.0
Cliff	13.5	11.4	12.3
Cave	18.9	14.3	14.0
Other	2.7	5.7	1.8
Tree species			
Douglas-fir		65.3	53.8
Ponderosa pine			18.0
White fir			12.8
Pinyon pine	79.2		2.6
Box-elder/maple	16.7	26.9	12.8
Utah juniper	4.2	7.7	

Table 4.11b. Selected characteristics of roost sites used by radio-tagged Mexican spotted owls in the Upper Gila Mountains Recovery Unit. Values shown are mean (± standard deviation) for continuous variables, % for categorical variables.

	Study Area			
Variable	San Francisco Peaks (n=4 owls, 66 roosts)[1]	Walnut Canyon (n=2 owls, 36 roosts)[1]	White Mountains (n=2 owls, 16 roosts)[1]	Bar M Watershed (n=13 owls, 458 roosts)[2]
Elevation (m)	2,519 (83)	2,048 (50)	2,361 (113)	2,168 (86)
Slope (%)	47 (22)	117 (71)	52 (26)	17 (6)
Roost tree dbh (cm)	41 (19)	27 (6)	43 (18)	32 (4)
Roost tree height (m)	17 (5)	13 (3)	23 (10)	16 (1)
Overstory height (m)				21 (2)
Canopy closure (%)	79 (7)	75 (9)	78 (8)	69 (7)
Aspect				
E	40	27	13	12 (15)
S	32	0	12	28 (15)
W	9	6	31	40 (20)
N	19	67	44	20 (12)
Cover type				
Mixed conifer	89	47	100	
Ponderosa pine	11			2 (2)
Pine oak				98 (2)
Mixed broadleaf		53		
Pinyon juniper				
Perch type				
Tree	100	67	100	99 (3)
Snag				1 (3)
Cliff		22		
Cave		11		
Tree Species				
Douglas fir	44	63	56	
Ponderosa pine	30	8	13	85 (13)
White fir	24		19	
Gambel oak				15 (13)
Box elder		29		
Other	2		12	
Slope position				
Upper third	35	24	6	40 (27)
Middle third	32		38	36 (16)
Lower third & canyon bottom	33	76	56	24 (15)

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Table 4.11c. Selected characteristics of roost sites used by radio-tagged Mexican spotted owls in the Basin and East Range Recovery Unit. Values shown are mean (± standard deviation) for continuous variables, % for categorical variables.

	Study Area			
Variable	Sacramento Mountains: mixed conifer (n=5 owls, 156 roosts)[1]	Sacramento Mountains: mixed conifer (n=8 owls, 374 roosts)[2]	Sacramento Mountains: xeric mixed forest (n=4 owls, 174 roosts)[3]	Sacramento Mountains xeric mixed forest (n=7 owls, 372 roosts)[2]
Elevation (m)		2,566 (56)		2,272 (104)
Slope (%)	21 (9)	35 (7)	23 (10)	35 (5)
Roost tree dbh (cm)		43 (8)		29 (2)
Roost tree height (m)	23 (9)	21 (3)	16 (6)	15 (3)
Overstory height (m)		28 (1)		21 (1)
Canopy closure (%)	83 (15)	76 (3)	75 (10)	68 (3)
Aspect				
E		49 (28)		32 (14)
S		21 (15)		5 (4)
W		4 (4)		6 (6)
N		27 (29)		56 (19)
Cover type				
Mixed conifer	88	97 (8)		87 (7)
Ponderosa pine				3 (4)
Pine oak				8 (7)
Pinyon juniper				3 (4)
Other		3 (7)		
Perch type				
Tree		97 (3)		96 (7)
Snag		3 (3)		3 (5)
Cliff				1 (3)
Cave				
Tree species				
Douglas fir	65	40 (18)	43	59 (12)
Ponderosa pine	4	2 (3)	38	15 (6)
White fir	23	35 (17)	6	4 (9)
Gambel oak		14 (4)		11 (8)
Box elder				
Other	8	9 (11)	13	12 (9)
Slope position				
Upper third		14 (7)		18 (11)
Middle third		24 (9)		22 (9)
Lower third & canyon bottom		62 (16)		60 (13)

[1] Ganey (1988)

[2] Ganey and Block (unpublished data). Characteristics first averaged for individual owls, then averaged across owls. Values reported for categorical variables are means and SD of percentages for individual owls.

[3] Zwank et al. (1994)

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limitations discussed relative to nest sites (see above) described by Fletcher and Hollis (1994).

Ninety-five percent of all roosts were in trees, with the remainder on cliffs or in caves (Fletcher and Hollis 1994: fig. 42). Percent slope averaged 46 ± 34%, with 45% of all roost sites occurring on slopes >40% (Fletcher and Hollis 1994: fig. 46). Most (57%) of these roost sites were found on the lower third of slopes (Fletcher and Hollis 1994: fig 47).

Of 367 roost sites where cover type was recorded, 65.7% were in mixed conifer, 27.2% in pine-oak, 2.7% in riparian, 1.4% in ponderosa pine, and 3.0% in other cover types (Fletcher and Hollis 1994: fig. 49). A variety of trees provided roost perches, including Douglas-fir (38.3%), Gambel oak (17.9%), ponderosa pine (11.9%), white fir (11.4%), other oak species (8.0%), and other species (12.4%; Fletcher and Hollis 1994: fig. 53; n = 402). Trees <15.2 cm (<6 in) dbh accounted for 8.8% of all roosts, with 41.7, 24.1, 11.1, and 14.3% in trees from 15.2-30.5, 30.5-45.7, 45.7-61, and >61 cm (6-12, 12-18, 18-24, and >24 in) in dbh, respectively (Fletcher and Hollis 1994: fig. 54).

Ganey and Block (unpublished data) evaluated seasonal differences in roost site characteristics in ponderosa pine-Gambel oak forest (Table 4.12). Canopy closure was greater at roosts used during the breeding season. Owls used Gambel oak significantly more often during the breeding season, and tended to roost more often on the upper third of slopes during the breeding season and on the middle third during the nonbreeding season.

Ganey and Block (unpublished data) also reported some characteristics of winter roosts used by two owls that migrated to lower elevations (Table 4.13). Both owls roosted primarily in pinyon-juniper woodland, on the middle and upper portions of slopes. They typically perched low in short juniper trees, well hidden by dense foliage and near the center of the tree. These winter roosts differed greatly in structure and species composition from typical summer roosting habitat.

WINTERING HABITAT

Present knowledge of wintering habitat of Mexican spotted owls comes primarily from radiotelemetry studies (see Patterns of Habitat Use at the Home Range Scale) and opportunistic observations of wintering adults. Radiotelemetry studies indicate that many owls remain on their breeding areas throughout the year, whereas some migrate off of the study area. Where wintering areas of migrants have been located, they are typically in lower elevation woodland or scrub habitats with more open structure than typical breeding habitat. However, one owl in the Colorado Plateau RU migrated upwards in elevation to winter in coniferous forest (Willey 1993).

Opportunistic sightings of spotted owls during the winter also suggest that part of the population moves to lower elevations. For example, owls have been sighted in lower Sabino Canyon, outside of Tucson, Arizona, and on golf courses in Tucson in recent winters (Russell Duncan, Southwestern Field Biologists, Tucson, AZ, pers. comm.). An adult owl banded on the Gila National Forest, Upper Gila Mountains RU, was recovered during winter 1995 near Deming, New Mexico, Basin and Range-East RU. This bird had apparently traveled approximately 160 km (100 mi) from the area where it was located during the breeding season, from high-elevation forest to Chihuahuan desert (Mark Seamans, Humboldt State Univ., Arcata, CA, pers. comm.).

In summary, available evidence on wintering habitat is limited, but suggests that the bulk of the owl population is nonmigratory. Where migration does occur, it typically involves movement to lower, warmer, and more open habitats. In some cases, migration involves movement between adjacent Recovery Units. Little quantitative data exists to describe typical wintering habitat for either migrants or year-round residents.

DISPERSAL HABITAT

Very little is known about habitat use either by adults during migration or by juveniles

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Table 4.12. Seasonal roost site characteristics of radio-tagged Mexican spotted owls in ponderosa pine-Gambel oak forest, Arizona (Upper Gila Mountains Recovery Unit). Data from Ganey and Block (unpublished). Values shown are mean (± SD) for continuous variables, % for categorical variables.

	Season	
Variable	**Breeding (Mar-Sep; n=13 owls, 206 roosts)**	**Nonbreeding (Oct-Feb; n=13 owls, 252 roosts)**
Elevation (m)	2,144 (114)	2,158 (83)
Slope (%)	18 (13)	16 (11)
Roost tree dbh (cm)	32 (14)	31 (11)
Roost tree height (m)[1]	15 (7)	16 (6)
Canopy closure[1]	79 (16)	67 (18)
Cover type		
Ponderosa pine	1	3
Pine-oak	99	97
Tree species[2]		
Ponderosa pine	62	96
Gambel oak	38	4
Slope position[2]		
Upper third	46	34
Middle third	24	42
Lower third	30	23
Aspect		
E	12	12
S	19	33
W	42	39
N	27	16

[1] Variable differs significantly ($P < 0.05$) between seasons, based on t test.

[2] Variable differs significantly ($P < 0.05$) between seasons, based on chi square test.

Table 4.13. Characteristics of roost sites used by two migrant Mexican spotted owls on their winter range. Both owls bred in ponderosa pine-Gambel oak forest in the Upper Gila Mountains Recovery Unit, and wintered in pinyon-juniper woodland on the Basin and Range-West Recovery Unit. Data from Ganey and Block (unpublished).

Variable	n[1]	Mean	Standard Deviation
Elevation (m)	32	1,342	57
Slope (%)	33	33	17
Roost tree dbh (cm)	5	35	13
Roost tree height (m)	33	6	2
Overstory height (m)	24	7	2
Canopy closure (%)	7	29	27
Cover type (%)	37		
Pinyon-juniper		100	
Roost tree species (%)	36		
Pinyon pine		8	
Juniperus spp.		92	
Slope position (%)	35		
Upper third		43	
Middle third		57	

[1] Small sample sizes for some variables due to low owl perch height and consequent inability to approach closely for habitat sampling without flushing the owl.

during dispersal. Willey (1993) monitored seven dispersing juvenile owls in Utah. These juveniles apparently moved through a variety of habitat types, including several that might generally be considered too open for use by spotted owls. None of these juveniles survived to reproduce.

A. Hodgson and P. Stacey radio tagged five juveniles in the San Mateo Mountains, New Mexico (Upper Gila Mountains RU). Two juveniles apparently dispersed across open grassland to the Black Range, but their ultimate fate is not known (Peter Stacey, Univ. of Nevada, Reno, pers. comm.). Three other juveniles apparently remained in the San Mateo Mountains. No information is available on habitats used by these owls.

ADDITIONAL STUDIES

In addition to the above studies, two additional studies are treated separately here because they either were not specific to a single scale (Johnson 1989, Dames and Moore 1990) or did not distinguish between site types (Dames and Moore 1990). Johnson (1989) compared habitat characteristics sampled at one roost and one nest site with characteristics sampled at 20 points within the same stand. Thus, this provides a comparison of site characteristics with overall characteristics of the surrounding stand. Mean tree height, overstory basal area, understory basal area, overstory density, and snag density were all greater at the roost and nest sites than in the surrounding stand. Despite the greater understory basal area at roost and nest sites, understory density was greater within the stand, suggesting that the understory at the roost and nest sites contained fewer but larger trees (Johnson 1989:12). Johnson (1989:14-15) further noted that the roost and nest sites ranked high (relative to the stand) for evenness indices for both tree species and diameter, and suggested that small-scale diversity may be an important factor in habitat selection by spotted owls (see also Johnson and Johnson 1988, Johnson 1990).

Dames and Moore (1990) reported on habitat characteristics in areas occupied by Mexican Spotted Owls in Arizona and New Mexico (Upper Gila Mountains and Basin and Range East-RUs). Sampling methods and sampled area differed between states (Dames and Moore 1990:10), and most of the area sampled was based on owl presence in the area, rather than on specific evidence of use by owls for either foraging, roosting, or nesting. Results of hypothesis tests regarding habitat characteristics in this study were inconclusive. In both states, the most consistent feature within and among areas sampled was variability (Dames and Moore 1990: executive summary).

CONCLUSIONS

Habitat Relationships

Several patterns are evident upon evaluation of current knowledge regarding habitat relationships of Mexican spotted owls. The first is that most information is limited to relatively fine spatial scales. For example, we have considerable information about roost and nest trees, and roost and nest sites, but have little information on stands used by owls, habitat composition of owl home ranges, or landscape configurations used by spotted owls. Second, most information on owl habitat use relates to the breeding season, and to habitats used for nesting and/or roosting. We know little about habitat use during winter or dispersal periods, or about what constitutes adequate foraging habitat. Third, most information on owl habitat use and selection comes from correlative studies that do not demonstrate cause-and-effect relationships. Fourth, our knowledge of owl habitat-use patterns comes from a very short time period (mainly 1984-present).

All of these factors limit our ability to define what constitutes spotted owl habitat, or what desired future conditions should be for spotted owls. What we can do is describe features of breeding-season roosting and nesting habitat used by owls at this time. In most cases, historical information is not adequate to know whether currently-occupied sites were also occupied in the past, or to allow us to draw conclusions about structural features of habitats used in the past.

Spotted owls typically nest or roost either in deep, rocky canyons, or in any of several forest cover types. The relative use of canyons versus forests varies among regions. For example, owls in parts of the Colorado Plateau RU are found exclusively in deep, rocky canyons, whereas owls in many other RUs are found primarily in forests (although these forests are often in canyons).

Where owls occur in forests, they typically select large, old trees for nesting. Nest and roost sites are found primarily in mixed-conifer forest (Table 4.1), although pine-oak forests are also used in some areas, such as parts of the Upper Gila Mountains, Basin and Range-West, and Sierra Madre Occidental-Norte RUs (Table 4.1; see also Ganey and Balda 1989a, Duncan and Taiz 1992, Ganey et al. 1992, Fletcher and Hollis 1994, Tarango et al. 1994, Seamans and Gutiérrez in press). Nest and roost sites typically contain structurally-complex, uneven-aged forests, with a variety of age- and/or size- classes, a large tree component, many snags and down logs, and relatively high basal area and canopy closure (Tables 4.6-4.11; see also SWCA 1992, Armstrong et al. 1994, Ganey and Balda 1994, Ruess 1995, Seamans and Gutiérrez in press). Diversity of tree species and diameters appears to be high in many owl nesting and roosting areas (Johnson and Johnson 1988, Johnson 1989, Johnson 1990, Seamans and Gutiérrez in press). Many roost and nest sites are found in canyon bottoms or low on canyon slopes (Table 4.11; see also Ganey and Balda 1989a, Fletcher and Hollis 1994, Tarango et al. 1994:36, Seamans and Gutiérrez in press). Many have a conspicuous broadleaved component, in the form of riparian trees or especially various oaks (Ganey and Balda 1989a, Duncan and Taiz 1992, Ganey et al. 1992, SWCA 1992. Tarango et al. 1994, Ruess 1995, Seamans and Gutiérrez in press).

The reasons why spotted owls nest and roost in structurally-complex, diverse forests and deep canyons have not been conclusively demonstrated. Barrows (1981) suggested that owls seek dense forest stands as protection from high daytime temperatures. This explanation is attractive with respect to Mexican spotted owls, because the most apparent common denominator between the types of forests and deep, rocky canyons used is that both situations provide cool microsites (Kertell 1977, Ganey et al. 1988, Ganey and Balda 1989a, Rinkevich 1991, Willey 1993). Further, there is some evidence that, relative to the great horned owl, which is found in hotter and drier areas, the spotted owl has difficulty dissipating metabolic heat at high temperatures (Ganey et al. 1993).

Carey (1985) and Gutiérrez (1985) also hypothesized that northern spotted owls might seek dense old, closed-canopy forests because such areas supported higher prey densities, or because the owls were better able to avoid predators in such areas. Present information, however, suggests that owls forage in a wider variety of forest types than are used for roosting (Ganey and Balda 1994, see also Ward and Block 1995). Further, although owls in one study roosted primarily in unlogged mixed-conifer forests, they did not show a strong pattern of selection for such forests when foraging (Table 4.4). This suggests that the association between spotted owls and mixed-conifer forest may be driven more by roosting and/or nesting behavior than by foraging behavior (Ganey and Balda 1994). We currently have no information with which to test the hypothesis that spotted owls are better able to avoid predators in complex forests or deep, rocky canyons.

In summary, at present we suspect that selection of typical nesting and roosting habitat is driven primarily by microclimatic considerations. Prey availability may also be an important consideration, however, and prey density in and around an area with microclimatic conditions typical of nest/roost habitat may determine whether or not that site is used by owls. Prey availability may also determine how large an area owls must use to meet their energetic needs (Carey et al. 1992, Verner et al. 1992, Zabel et al. 1995). However, we suspect that the primary factor limiting spotted owl distribution is the presence on the landscape of habitat suitable for roosting and nesting.

In some areas, the types of forests used for roosting and nesting are primarily restricted to canyon situations. This is particularly true at lower elevations, where mixed-conifer forest is generally found only in canyon bottoms or on north-facing canyon slopes. Thus, the distribution of roosting and nesting habitat, and of spotted owls in these areas, is naturally fragmented and discontinuous. Opportunities for increasing the amount of spotted owl habitat in such areas are limited, and management efforts would be better focused on preserving and enhancing habitat where it exists. Replacement habitat in such areas may need to develop *in situ* following stand-replacing disturbances.

In other areas, such as high-elevation mixed-conifer forest, it may be possible to develop spotted owl habitat over more of the landscape. An example of such an area is the Sacramento Mountains (Lincoln National Forest, Basin and Range-East RU). Spotted owls are abundant and widely distributed in mixed-conifer forests across this range (Skaggs and Raitt 1988, Fletcher and Hollis 1994: fig. 24). Much of this area was subject to relatively intensive railroad logging early this century (Glover 1984), but these forests have recovered quickly and attained structural complexity (Table 4.8b), demonstrating that development of replacement habitat is possible after management under some circumstances. In areas such as this, managers might combine protection of existing habitat with attempts to develop replacement habitat over time, in a more dynamic approach to habitat management.

Comparisons With Other Subspecies of Spotted Owls

There are many similarities in habitat-use patterns of the three subspecies (northern, California, and Mexican) of spotted owls. For example, all three appear to be most common in structurally-complex forest environments, although floristic composition of habitats used varies both within and between subspecies' ranges (for other subspecies see reviews in Thomas et al. 1990, Gutiérrez et al. 1992). Both the California (Gutiérrez et al. 1992) and Mexican subspecies most commonly nest in mixed-conifer forest, followed by forest types dominated by oaks or conifers and oaks. Both the California (Gutiérrez et al. 1992) and Mexican subspecies appear to use a wider variety of habitat conditions for foraging than for roosting and nesting. These consistencies in habitat use patterns between subspecies occupying different geographic areas and habitat types further strengthen our conclusion that spotted owls are seeking particular types of habitat features for nesting and roosting.

Habitat Trends

Because the listing of the owl was based partially on projected declines in owl habitat, it is worth discussing what we know about trends in owl habitat. The following discussion focuses separately on various habitat conditions used by spotted owls. It is largely restricted to trends in roosting and nesting habitat, because most of our information relates to such areas, and because such habitat is thought to limit spotted owl distribution. Finally, because little historical information exists with respect to the type of microsite conditions that describe roosting and nesting habitat of spotted owls, this discussion is necessarily largely qualitative.

Rocky Canyons

Mexican spotted owls are found primarily in rocky canyons in parts of their range, such as southern Utah (Kertell 1977, Rinkevich 1991, Willey 1992, 1993, Utah Mexican spotted owl Technical Team 1994). In other areas, part of the population also inhabits rocky canyons, but these are generally more heavily forested than the slickrock canyons found in parts of the Colorado Plateau RU (Ganey and Balda 1989a, USDA Forest Service 1993, Fletcher and Hollis 1994). There is little evidence for change in habitat quality or loss of habitat in slickrock canyons. Canyon-bottom vegetation may have been degraded by grazing in some cases (see below), and some habitat may have been lost beneath large reservoirs along the Colorado River and its tributaries. The latter change could have decreased connectivity among remaining populations. Otherwise, we suspect that habitat trends are relatively stable in areas where owls are found primarily in slickrock canyons.

Riparian Forests

Historically, owls were found in low-elevation riparian forests (Bendire 1892, Phillips et al. 1964, and possibly Woodhouse 1853). These forests have undergone extensive modification because of recreation, flood control, livestock grazing, and modification of natural water tables (Knopf et al. 1988; see also Kennedy 1977, Kauffman and Krueger 1984, Minckley and Clark 1984, Skovlin 1984, Minckley and Rinne 1985, Platts 1990, Schulz and Leininger 1990, Dick-Peddie 1993). Collectively, these activities and other factors have changed the species composition and structure of riparian forests. In extreme cases, riparian forests have disappeared entirely. No breeding spotted owls have been documented in lowland riparian forests in recent times. Surveys of such habitat have been far from exhaustive, and owls may still inhabit some remnant riparian forests. Nevertheless, the overall trend with respect to spotted owls breeding in lowland riparian forest habitat has clearly been negative.

Spotted owls also commonly occur in canyon-bottom riparian forests at higher elevations, interspersed with other forest types. In many cases these forests have also been degraded (Schulz and Leininger 1991, see also Fleischner 1994). Management to retain and enhance these riparian forests would likely be beneficial to spotted owls (as well as many other plants and animals).

Coniferous Forests

Trends in coniferous forests are more difficult to evaluate. It is clear that changes have occurred in southwestern forests. These stem primarily from three sources: disruption of natural disturbance regimes, grazing, and timber harvest. Many decades of fire suppression have disrupted natural disturbance regimes (Cooper 1960, Madany and West 1983, Stein 1988, Savage and Swetnam 1990, Covington and Moore 1992, 1994, Harrington and Sackett 1992, Johnson 1995). The absence of frequent, low-intensity fire, coupled with widespread overgrazing by livestock in the late 1800s, reduced competition between herbaceous vegetation and tree seedlings. These effects produced a good seedbed for conifer regeneration, and generally resulted in increases in tree densities on forested lands (Rummel 1951, Madany and West 1983, Zimmerman and Neuenschwander 1984, Stein 1988, Savage and Swetnam 1990, Covington and Moore 1992, 1994, Harrington and Sackett 1992, Johnson 1995, Ruess 1995). Such increases in tree density can not only alter stand structure, but can also lead to declines in shade-intolerant tree species, and drive ecological succession from one forest type to another. For example, some ponderosa pine forests appear to be converting to mixed-conifer forest.

Timber harvest in many areas has also altered stand structure and sometimes species composition. Timber harvest can occur in different forms, with different intensity, and with different effects on stand structure. In many cases, however, the net effect of timber harvest is a decrease in old trees and at least a short-term decrease in tree density and basal area. In these respects timber harvest tends to work opposite the effects of disruptions in natural disturbance regimes described above. Where timber harvest targets shade-intolerant species, however, it could further the trend of ecological succession towards shade-tolerant species.

The net effect of these processes on amount and quality of spotted owl habitat is difficult to determine. USDI (1993:14251), citing Fletcher (1990), postulated that spotted owl habitat had decreased in amount due to timber harvest. Fletcher and Hollis (1994:29) estimated that 1,068,500 ac of forested habitat in Arizona and New Mexico had been rendered unsuitable for spotted owls due to human activities, primarily timber harvest, through 1993. Conversely, Hull (1995:7) reported that "thousands of acres have converted from ponderosa pine to mixed-conifer," and argued that the amount of Mexican spotted owl habitat had increased. For several reasons, we submit that either viewpoint is difficult to substantiate with presently-available data.

First, the claim that thousands of acres of ponderosa pine have converted to mixed-conifer is unsubstantiated. Johnson (1995: fig.1) shows a large increase in acreage of mixed-conifer in Arizona and New Mexico between 1966 and 1986, based on forest inventories conducted in those years. Johnson (1995:1) also presents numbers suggesting that much of the increase in mixed-conifer forest is due to invasion of meadows, rather than conversion of ponderosa pine forest. Further, this information is extrapolated from data presented in the original inventories (Choate 1966, Spencer 1966, Conner et al. 1990, Van Hooser et al. 1993), and no information is provided on how that extrapolation was done. Therefore, it is impossible to assess the accuracy of the figures presented. Methods and definitions may also have changed between inventories. Referring to comparisons between the 1986 inventory and earlier inventories, Van Hooser et al. (1993:1) state: "The changes in definitions and survey standards make detailed comparisons with previous inventory results unwise."

Second, the idea that all mixed-conifer forest is spotted owl habitat is not supported by the available data. As noted previously, owls roost and nest primarily in structurally-complex forests with particular features, including large, old trees. Recent invasion of meadows by mixed-conifer forest is unlikely to have created this type of habitat. If that process proceeds, however, it could create owl habitat in the future.

Finally, most available data on historical forest structure and increases in forest density relate to ponderosa pine forest (USGS 1904, Woolsey 1911, Harrington and Sackett 1984, Covington and Moore 1992, 1994). As we have shown here, this forest type is not typically used for roosting and nesting by spotted owls. Data presented by Ruess (1995) suggest that similar changes have occurred in ponderosa pine-Gambel oak forest, which is used by spotted owls. No such data exist for mixed-conifer forest, however, which is the primary type used by spotted owls for roosting and especially for nesting. It seems logical to assume that increases in density have also occurred within this forest type. Without quantitative data on changes in this forest type, however, determining whether or not such changes have been favorable to spotted owls is essentially impossible.

In summary, conflicting speculation exists regarding trends in spotted owl habitat in coniferous forest. Some authors speculate that timber harvest has reduced the amount of owl habitat, whereas others speculate that fire suppression has increased the amount of owl habitat. Data presented here suggest that spotted owl habitat is complex. The types of historical evidence available do not allow for any clear analysis of trends in such habitat. We recognize that we cannot return to the past to collect such data, but we can learn from this situation. Our inability to evaluate habitat trends strongly emphasizes the need for accurate and comprehensive inventory and monitoring of forest resources, so that in the future changes in forest habitat can be assessed over time.

Research Considerations

Clearly, much remains to be learned about habitat relationships of the Mexican spotted owl. Gutiérrez et al. (1992) outlined a number of research considerations relative to habitat relationships of the California spotted owl. These are all relevant to the Mexican subspecies as well. We briefly summarize some additional considerations here.

Quantitative data on patterns of owl habitat use are largely or completely lacking for some geographic regions, habitat types, and spatial scales. Particularly striking is the lack of quantitative data on habitat relationships at the stand and landscape scales. Some estimates of habitat conditions measured on small plots, such as canopy closure, may not be representative of conditions at the stand scale. Further, many management actions are planned at a stand scale, and implementation of ecosystem management approaches will require more attention to habitat composition and pattern at the landscape scale. Thus, it seems critical to obtain better information at these (as well as other) scales. The Team's efforts to evaluate habitat use patterns at the landscape scale were frustrated by the lack of suitable GIS coverages. Development of such coverages would greatly facilitate future analyses. Further, any credible attempts to monitor amounts of spotted owl habitat or trends in such habitat will require both better data on what constitutes spotted owl habitat at various spatial scales, and better data on forest structure across the landscape.

Most studies of habitat use-patterns have been correlative rather than experimental, which limits our ability to draw conclusions about habitat selection by Mexican spotted owls. Further, even where correlates of owl occupancy have been identified, these characteristics have not been linked to owl fitness. Demographic studies of Mexican spotted owls are underway in a few areas. Far greater efforts will be required to obtain the data necessary to determine which habitats or areas contain self-supporting populations, and to evaluate habitat composition within those areas.

In the meantime, forest management is ongoing, and we assume that this will continue. Although controlled experiments in forest management are exceedingly difficult to design and conduct, forest management activities could provide a great opportunity to learn more about the response of spotted owls to habitat configurations at various scales. Experimental silvicultural prescriptions could be developed and applied, guided by current knowledge of habitat conditions. Such knowledge should be supplemented by studies of owl habitat in other areas and habitats, and at other scales. McKelvey and Weatherspoon (1992) provide an example of a conceptual approach to integrating silviculture with knowledge of stand structures used by spotted owls.

Finally, little attention has been paid to the ecology and habitat relationships of the owl's principal prey species (but see Ward and Block 1995), and to how forest management might influence population levels of these species. Management actions could indirectly affect spotted owls, either positively or negatively, through effects on their prey species. Therefore, these species should also be considered in future management planning and research activities.

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CHAPTER 5: Mexican Spotted Owl Prey Ecology

James P. Ward, Jr., and William M. Block

In addition to shelter, water, and other requirements, habitat must also provide spotted owls with food. Certain trees within specific forest communities may meet nesting, roosting, and perching needs, but the tree component alone may not necessarily sustain the animal species upon which the owls prey. Conserving appropriate habitat for the owl includes conserving habitat for a suite of prey species.

The distribution and abundance of prey often influence the distribution, abundance, and reproduction of raptors (Newton 1979). In owls, reproductive success is often correlated with prey abundance (Craighead and Craighead 1956, Southern 1970, Lundberg 1976, Wendland 1984, Korpimäki and Norrdahl 1991). The postulated mechanism behind this relationship is energetically based. Male owls must provide enough food to their female mates during incubation and brooding to prevent abandonment of nests or young (Johnsgard 1988). Accordingly, ecologists suspect that spotted owls select habitats partially because of the availability of prey (Carey 1985, Thomas et al. 1990, Verner et al. 1992). Understanding the natural history of the spotted owl's primary prey is vital information for the Recovery Plan because it provides resource planners and managers with another tool for evaluating an area's ability to support spotted owls.

This section summarizes information about spotted owl-prey relationships and the ecology of the owl's prey. Specifically, our objectives are to: (1) describe the diet of the Mexican spotted owl; (2) identify prey that may influence owl fitness; and (3) quantify habitat correlates of the owl's primary prey.

Ideally, relationships among the Mexican spotted owl, its prey, and the prey's habitat should be examined across different spatial and temporal scales. In reality, the available information permits only a limited view of the owl's prey ecology. For example, we could describe abundance and distribution of the owl's common prey among different vegetation communities, but could not provide a direct link between owl habitat use and prey availability. Although the latter information is preferred for prioritizing habitat conservation, our approach relies upon conserving a general mixture of habitats for the owl and its prey throughout major portions of the owl's range. In time, information from more specific studies should be used to refine the general findings presented here.

METHODS FOR DETERMINING OWL DIETS

The dietary habits of raptors can be determined both directly and indirectly. Observations of prey capture and of prey taken to roosts or nests provide direct evidence of a raptor's diet. However, such observations are difficult to obtain from nocturnal foragers like owls and offer little opportunity for quantitative analysis. Regurgitated pellets of undigested materials (fur, feathers, bones, chitinous exoskeletons) offer an indirect, alternative method for analyzing the feeding habits of owls (Errington 1930, Glading et al. 1943, Marti 1987).

Spotted owl prey are identified by examining the contents of pellets collected below roosts and nests. Prey remains are identified to species, genus, or a less specific prey category and tallied. Diets are then quantified using two measures, relative frequency and percent biomass (Forsman et al. 1984, Marti 1987). Relative frequency of prey is expressed as the number of individual items of a given prey species or group divided by the total number of all individual items found in a sample. Biomass (g) is the total number of items of a given prey species or group multiplied by the average mass (g) for that species or group. Commonly, both relative frequency and biomass are expressed as percentages. Both measures can be used to compare owl diets among sampling units such as reproductive groups, locations, seasons, and so on. The two measures provide different information. Measures of relative frequency indicate the proportion of each prey type in the owl's diet by number, whereas,

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percent biomass indicates the proportion of each prey type by weight.

Pellets may provide biased measures of owl diets. Pellets are typically collected opportunistically below roosting owls or from known roost groves, not randomly or systematically. The bias potentially resulting from nonrandom sampling could not be evaluated. We assumed that items found in pellets reflected the true proportions of prey species in owl diets. The methods we used to quantify Mexican spotted owl diet are comparable to other studies conducted on the northern and California subspecies (see reviews by Thomas et al. 1990 and Verner et al. 1992). Accordingly, we restricted analyses and inferences to relative comparisons.

We compiled and analyzed prey remains of Mexican spotted owls as reported in 13 studies conducted since 1977 (Tables 5.1-5.6). A total of 11,164 prey items was examined. These data consisted of 25 data sets from 18 geographic areas throughout the owl's range, and included most published and unpublished information of Mexican spotted owl diet through 1993 (Tables 5.1-5.6). Kertell (1977) was not used because of the small number of items reported.

Each data set differed in the number of owls, years, and pellets examined. In some cases, the number of owls studied or pellets collected were not recorded. Thus, we could not use owls as the sampling unit or separate differences among owl territories in region-wide analyses. However, each data set contained a known number of identified prey items. For analysis, we treated each prey item as an observation and each data set as a dietary sample. Following this logic, the number of observations in a sample (i.e., sample size) corresponds to the total number of prey items identified in each data set. We justified the use of prey items as an observational unit instead of pellets because a pellet is difficult to define (i.e., broken pellets are often collected or multiple pellets are stored together and break apart during storage) and a single pellet may contain multiple prey items. Being an uncertain and inconsistent measure of sample size, no pellet total is given here.

The methods used to identify remains and tally prey numbers followed Forsman et al. (1984). Samples abbreviated as CAPRF2, ZION2, CANYL, BAR-M, MOGAZ2, COCODM, GILADM, and SACMT2 (see Tables 5.1-5.6 for acronym definition) were analyzed using standardized procedures described and implemented by DeRosier and Ward (1994) to facilitate comparison. According to both sources, remains were keyed to species when possible using skulls and appendicular skeletal parts. Specialists were consulted to identify less common or unusual remains, particularly bats, birds, reptiles, and invertebrates.

Deviations from our standard identification procedures were necessary for the SCCOL sample where invertebrate parts were not identified (Charles Johnson, Rocky Mountain Research Station, Fort Collins, CO, pers. comm.), and in the ZION1 sample where appendicular parts were not used to tally prey (Sarah Rinkevich, FWS, Albuquerque, NM, pers. comm.).

Owl diets were quantified using relative frequency and percent biomass for 11 prey groups: woodrats, white-footed (peromyscid) mice, voles, pocket gophers, rabbits, bats, other or unidentified small mammals (mostly murids), other or unidentified medium mammals (mostly sciurids), birds, reptiles, and arthropods (Tables 5.1-5.6). We use the term peromyscid mice here in place of white-footed mice to represent the approximate 15 North American species of the genus *Peromyscus*. Confusion sometimes follows discussion of white-footed mice because this is also the common name for *P. leucopus*.

Several sources were used to estimate prey mass (Appendix 5a). Biomass estimates given by the original authors were retained unless better estimates were available. Estimates of prey mass from areas nearest to where pellets were collected were used whenever possible. In the absence of better data, general references for mass were used. Averages, weighted according to proportions of species in owl diets, were used to estimate biomass for less specific taxa such as "woodrat species" or "unidentified bat."

Table 5.1. Relative frequency of prey items found in the diet of Mexican spotted owls occurring in the northern portion of the subspecies' range. Values were calculated from totals pooled across owl territories and years.

	Colorado Plateau							S. Rocky Mtn. Colorado	S. Rocky Mtn. New Mexico
	CAPRF1	**CAPRF2**	**ZION1**	**ZION2**	**CANYL**	**MESAV**	**BLACK**	**SOCO**	**NNMEX**
Prey Group	Capitol Reef N.P. (1977)	Capitol Reef N.P. (1991-92)	Zion N.P. (1989-91)	Zion N.P. (1991-93)	Canyonlands N.P. (1992-93)	Mesa Verde N.P. (1991-92)	Black Mesa (1984-90)	Southern Colorado (1991-93)	Northern New Mexico (1985-91)
Woodrats	72.4%	26.8%	61.5%	40.8%	26.5%	58.4%	57.4%	18.6%	32.3%
Peromyscid mice	15.2%	49.7%	12.3%	13.2%	35.1%	27.0%	23.6%	38.9%	20.3%
Voles	0.0%	0.0%	0.0%	0.0%	0.4%	2.2%	2.2%	24.7%	8.2%
Pocket gophers	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.4%	0.7%	3.1%
Rabbits	0.0%	0.7%	0.0%	1.3%	0.0%	1.1%	1.1%	1.0%	5.0%
Bats	1.0%	8.5%	1.2%	0.0%	12.3%	2.2%	2.2%	3.3%	3.6%
Other Sm. Mammals	0.0%	2.0%	0.0%	6.6%	4.5%	5.6%	-----[a]	7.6%	1.4%
Other Md. Mammals	0.0%	2.6%	0.0%	19.7%	9.0%	0.0%	5.6%	0.3%	3.8%
Birds	0.0%	1.3%	0.0%	0.0%	2.2%	2.2%	1.1%	4.7%	11.4%
Reptiles	0.0%	1.3%	0.0%	0.0%	2.6%	1.1%	0.0%	0.0%	0.2%
Arthropods	11.4%	7.2%	25.0%	18.4%	7.5%	-----[b]	3.4%	-----[b]	10.5%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	99.8%	100.0%	100.0%
Number Years	1	2	3	3	2	2	1-7	3	1-7
Maximum Pairs	Unknown	1	8	1	1	2	Unknown	7	Unknown
Items_yr1		45	69	6	165	49		98	
Items_yr2		108	30	61	103	40		133	
Items_yr3			153	9				70	
Items_yr4									
Items_yr5									
Items	105	153	252	76	268	89	89	301	989
Source	Wagner et al. 1982	Willey Unpubl. Data	Rinkevich 1991	Willey Unpubl. Data	Willey Unpubl. Data	Johnson & Reynolds Unpubl. Data	Ganey 1992	Johnson & Reynolds Unpubl. Data	Reichenbacher & Duncan Unpubl. Rep.

[a] Other small animals were not separated from medium sized mammals in this study.

[b] Arthropods were not tallied in this study.

Table 5.2. Relative frequency of prey items found in the diet of Mexican spotted owls occurring in the central portion of the subspecies' range. Values were calculated from totals across owl territories and years.

	Upper Gila Mountains (Arizona)							Upper Gila Mountains (New Mexico)		
	WALCAN	**SANFRP**	**WHIMTN**	**MOGAZ1**	**BAR-M**	**COCODM**	**MOGAZ2**	**MOGNM**	**SWNM**	**GILADM**
Prey Group	Walnut Canyon (1984-90)	San Fran Peaks (1984-90)	White Mountains (1984-90)	Northern & Central Arizona (1985-91)	Northern Arizona (1989-93)	Northern Arizona (1991-93)	Mogollon Rim Arizona (1991-93	West-Central New Mexico (1985-91)	Tularosa Mountains (1991-93)	Southwest New Mexico (1985-91)
Woodrats	33.1%	18.5%	17.8%	33.8%	9.2%	9.8%	21.5%	34.3%	30.7%	14.5%
Peromyscid mice	26.9%	33.0%	20.4%	3.6%	35.7%	34.3%	22.7%	20.0%	20.2%	42.6%
Voles	14.3%	27.2%	37.6%	5.3%	1.9%	3.4%	8.8%	20.0%	1.8%	10.8%
Pocket gophers	6.0%	5.1%	5.7%	3.0%	4.4%	5.0%	3.1%	0.0%	2.6%	1.9%
Rabbits	6.4%	1.1%	5.1%	7.8%	1.3%	0.4%	2.3%	5.7%	2.6%	1.7%
Bats	1.7%	0.0%	0.0%	1.9%	0.7%	0.5%	0.0%	2.9%	16.7%	1.0%
Other Sm. Mammals	-----ª	-----ª	-----ª	1.9%	3.0%	9.6%	8.5%	2.9%	3.5%	4.1%
Other Md. Mammals	3.0%	3.3%	5.7%	5.3%	6.4%	7.8%	13.0%	2.9%	1.8%	7.7%
Birds	2.5%	2.9%	3.8%	11.1%	3.9%	4.6%	3.1%	8.6%	7.0%	4.0%
Reptiles	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.3%	0.0%	0.9%	0.0%
Arthropods	4.6%	9.1%	3.8%	26.3%	33.5%	24.5%	16.7%	2.9%	12.3%	11.7%
Total	100.0%	100.2%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0
Number Years	4	3	1-7	1-7	5	3	3	1-7	1-7	3
Maximum Pairs	5	7	11	Unknown	7	29	32	Unknown	Unknown	37
Items_yr1					13	264	94			305
Items_yr2					67	373	191			536
Items_yr3					541	682	68			517
Items_yr4					413					
Items_yr5					84					
Items	711	276	157	361	1118	1319	353	35	114	1358
Source	Ganey 1992	Ganey 1992	Ganey 1992	Reichenbacher & Duncan Unpubl. Rep.	Block & Ganey Unpubl. Data	Olson & Gutierrez Unpubl. Data	USDA For. Serv. Unpubl. Data	Reichenbacher & Duncan Unpubl. Rep.	Reichenbacher & Duncan Unpubl. Rep.	Seamans & Gutierrez Unpubl. Data

ª Other small animals were not separated from medium sized mammals in this study.

Table 5.3. Relative frequency of prey items found in the diet of Mexican spotted owls occurring in the southern portion of the subspecies' range. Values were calculated from totals pooled across owl territories and years.

	Basin and Range - West			**Basin and Range - East**		**Sierra Madre Occidental - Norte**
	SARIZ1	**SARIZ2**	**HAUCH**	**SACMT1**	**SACMT2**	**CHIHMX**
Prey Group	Southeast Arizona (1984-90)	Southeast Arizona (1985-91)	Huachuca Mountains (1987)	Sacramento Mountains (1985-91)	Sacramento Mountains (1991-93)	San Juanito Creel (1992-93)
Woodrats	22.4%	31.6%	37.4%	16.5%	8.2%	10.6%
Peromyscid mice	38.8%	30.1%	42.9%	10.8%	40.5%	35.0%
Voles	0.0%	0.0%	0.0%	33.1%	19.8%	0.9%
Pocket gophers	0.5%	2.4%	0.0%	5.0%	3.5%	4.0%
Rabbits	2.0%	2.1%	1.1%	8.6%	3.5%	0.9%
Bats	5.5%	3.9%	12.1%	3.6%	0.6%	2.2%
Other Sm. Mammals	-----[a]	1.5%	0.0%	2.2%	3.0%	2.7%
Other Md. Mammals	3.5%	0.4%	0.0%	0.7%	6.0%	2.2%
Birds	7.5%	14.2%	5.5%	9.4%	3.8%	6.2%
Reptiles	3.5%	0.4%	1.1%	0.0%	0.0%	0.0%
Arthropods	16.4%	13.3%	0.0%	10.1%	11.4%	35.4%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100 %
Number Years	1-7	1-7	1	1-7	3	2
Maximum Pairs	10	Unknown	1	6	39	8
Items_yr1					514	
Items_yr2					326	
Items_yr3					875	
Items_yr4						
Items_yr5						
Items	201	668	91	139	1715	226
Source	Ganey 1992	Reichenbacher & Duncan Unpubl. Rep.	Duncan & Snyder 1990	Reichenbacher & Duncan Unpubl. Rep.	Ward et al. Unpubl. Data	Tarango 1994

[a] Other small animals were not separated from medium sized mammals in this study

Table 5.4. Percent of prey biomass in the diet of Mexican spotted owls occurring in the norther portion of the subspecies' range. Values were calculated from totals pooled across owl territories and years.

	Colorado Plateau							S. Rocky Mtn. Colorado	S. Rocky Mtn. New Mexico
	CAPRF1	**CAPRF2**	**ZION1**	**ZION2**	**CANYL**	**MESAV**	**BLACK**	**SOCO**	**NNMEX**
Prey Group	Capitol Reef N.P. (1977)	Capitol Reef N.P. (1991-92)	Zion N.P. (1989-91)	Zion N.P. (1991-93)	Canyon-lands N.P. (1992-93)	Mesa Verde N.P. (1991-92)	Black Mesa (1984-90)	Southern Colorado (1991-93)	Northern New Mexico (1985-91)
Woodrats	98.5%	64.0%	98.4%	53.1%	57.4%	76.1%	81.7%	30.6%	47.7%
Peromyscid mice	1.4%	21.8%	1.4%	3.2%	14.0%	6.2%	4.8%	15.1%	5.0%
Voles	0.0%	0.0%	0.0%	0.0%	0.3%	1.5%	0.7%	27.2%	2.9%
Pocket gophers	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	3.2%	1.3%	4.1%
Rabbits	6.0%	5.0%	0.0%	5.4%	0.0%	11.1%	3.7%	16.7%	22.9%
Bats	0.1%	1.6%	0.1%	0.0%	1.9%	0.3%	0.5%	0.8%	0.6%
Other Sm. Mammals	0.0%	0.9%	0.0%	1.6%	1.5%	2.4%	——a	4.4%	0.3%
Other Md. Mammals	0.0%	4.8%	0.0%	36.5%	21.0%	0.0%	4.1%	0.3%	7.6%
Birds	0.0%	1.4%	0.0%	0.0%	2.9%	2.1%	0.6%	3.7%	10.1%
Reptiles	0.0%	0.5%	0.0%	0.0%	0.9%	0.4%	0.0%	0.0%	0.0%
Arthropods	0.1%	0.2%	0.2%	0.2%	0.1%	-----b	0.1%	——b	0.1%
Total	100.0%	100.0%	100.0%	100.0%	100.0	100.0%	99.2%	100.0%	100.0%
Number Years	1	2	3	3	2	2	1-7	3	1-7
Maximum Pairs	Unknown	1	8	1	1	2	Unknown	7	Unkown
Items_yr1		45	69	6	165	49		98	
Items_yr2		108	30	61	103	40		133	
Items_yr3			153	9				70	
Items_yr4									
Items_yr5									
Items	105	153	252	76	268	89	89	301	989
Source	Wagner et al. 1982	Willey Unpubl Data	Rinkevich 1991	Willey Unpubl Data	Willey Unpubl Data	Johnson & Reynolds Unpubl Data	Ganey 1992	Johnson & Reynolds Unpubl Data	Reichenbacher & Duncan Unpubl Rep

[a] Other small animals were not separated from medium-sized mammals in this study.
[b] Arthropods were not tallied in this study.

Table 5.5. Percent of prey biomass in the diet of Mexican spotted owls occurring in the central portion of the subspecies' range. Values were calculated from totals pooled across owl territories and years.

	Upper Gila Mountains (Arizona)							Upper Gila Mountains (New Mexico)		
	WALCAN	**SANFRP**	**WHIMTN**	**MOGAZ1**	**BAR-M**	**COCODM**	**MOGAZ2**	**MOGNM**	**SWNM**	**GILADM**
Prey Group	Walnut Canyon (1984-90)	San Fran Peaks (1984-90)	White Mountains (1984-90)	Northern & Central Arizona (1985-91)	Northern Arizona (1989-93)	Northern Arizona (1991-93)	Mogollon Rim Arizona (1991-93)	West Central New Mexico (1985-91)	Southwest New Mexico (1985-91)	Tularosa Mountains (1991-93)
Woodrats	50.0%	49.1%	36.6%	64.4%	38.2%	34.7%	62.7%	69.1%	56.6%	62.2%
Peromyscid mice	5.7%	12.5%	6.0%	0.8%	15.2%	13.9%	6.1%	4.7%	6.1%	12.6%
Voles	4.5%	15.0%	16.1%	1.3%	0.9%	1.5%	3.1%	5.4%	0.6%	6.2%
Pocket gophers	6.1%	9.1%	7.9%	3.6%	6.2%	12.9%	4.9%	0.0%	4.5%	2.1%
Rabbits	29.6%	6.7%	24.3%	31.3%	14.2%	3.4%	10.0%	25.1%	14.9%	9.2%
Bats	0.2%	0.0%	0.0%	0.3%	0.2%	0.1%	0.0%	0.5%	3.4%	0.1%
Other Sm. Mammals	—[a]	—[a]	—[a]	0.5%	1.0%	3.8%	1.7%	0.7%	0.2%	1.0%
Other Md. Mammals	2.3%	4.4%	6.0%	8.8%	15.6%	21.7%	28.0%	5.1%	4.5%	24.4%
Birds	1.9%	3.1%	3.1%	9.0%	8.2%	7.5%	3.2%	8.6%	8.8%	4.1%
Reptiles	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.2%	0.0%
Arthropods	0.1%	0.1%	0.1%	0.1%	0.4%	0.6%	0.2%	0.9%	0.3%	0.2%
Total	100.0%	100.0%	100.1%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Number Years	4	3	1-7	1-7	5	3	3	1-7	1-7	3
Maximum Pairs	3	7	11	Unknown	7	29	32	Unknown	Unknown	37
Items_yr1					13	264	94			305
Items_yr2					67	373	191			536
Items_yr3					541	682	68			517
Items_yr4					413					
Items_yr5					84					
Items	711	276	157	361	1118	1319	353	22	114	1358
Source	Ganey 1992	Ganey 1992	Ganey 1992	Reichenbacher & Duncan Unpubl. Rep.	Block & Ganey Unpubl. Data	Olsen & Gutierrez Unpubl. Data	USDA For. Serv. Unpubl. Data	Reichenbacher & Duncan Unpubl. Rep.	Reichenbacher & Duncan Unpubl. Rep.	Seamans & Gutierrez Unpubl. Data

[a] Other small animals were not separated from medium-size mammals in this study.

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Table 5.6. Percent of prey biomass in the diet of Mexican spotted owls occurring in the southern portion of the subspecies' range. Values were calculated from totals pooled across owl territories and years.

	Basin and Range - West			Basin and Range - East		Sierra Madre Occidental - Norte
	SARIZ1	SARIZ2	HAUCH	SACMT1	SACMT2	CHIHMX
Prey Group	Southeast Arizona (1984-90)	Southeast Arizona (1985-91)	Huachuca Mountains (1987)	Sacramento Mountains (1985-91)	Sacramento Mountains (1991-93)	San Juanito Creel (1992-93)
Woodrats	57.9%	57.3%	72.6%	26.1%	20.1%	36.0%
Peromyscid mice	14.3%	9.0%	6.6%	2.8%	12.0%	16.9%
Voles	0.0%	0.0%	3.3%	9.9%	12.1%	0.4%
Pocket gophers	0.9%	3.9%	0.4%	7.1%	4.8%	10.0%
Rabbits	11.9%	11.7%	0.5%	41.9%	26.0%	16.1%
Bats	1.5%	0.8%	0.3%	0.6%	0.2%	0.6%
Other Sm. Mammals		0.3%	0.1%	0.2%	1.6%	0.6%
Other Md. Mammals	4.5%	1.7%	0.4%	1.4%	19.3%	8.1%
Birds	7.7%	15.2%	1.8%	10.0%	3.8%	8.6%
Reptiles	0.9%	0.1%	0.3%	0.0%	0.0%	0.0%
Arthropods	0.3%	0.1%	0.0%	0.1%	0.3%	0.7%
Total	100.0%	100.1%	100.0%	100.0%	100.2%	100.0%
Number Years	1-7	1-7	1	1-7	3	2
Maximum Pairs	10		1	0	39	8
Items_yr1					514	
Items_yr2					326	
Items_yr3					875	
Items_yr4						
Items_yr5	201	668	91	139	1715	226
Source	Ganey 1992	Reichenbacher & Duncan Unpubl. Rep.	Duncan & Snyder 1990	Reichenbacher & Duncan Unpubl. Rep.	Ward et al. Unpubl. Data	Tarango 1994

Other small animals were not separated from medium-sized mammals in this study.

GENERAL FOOD HABITS

The Mexican spotted owl eats a variety of animals throughout its range but usually takes small and medium-sized mammals (Table 5.7). As a group, mammals are taken more frequently ($\bar{x}$ = 82.1%; cv = 13.3%; n = 25 data sets) than birds ($\bar{x}$ = 4.8%; cv = 78.4%; n = 25), reptiles ($\bar{x}$ = 0.5%; cv = 192.5%; n = 25) or arthropods ($\bar{x}$ = 12.6%; cv = 79.0%, n = 23). Arthropods could be present in the owl's diet because these items were eaten by the owl's prey prior to capture. Mammal use is even greater when biomass is considered ($\bar{x}$ = 95.8%, $\bar{x}$ = 3.9% for birds, $\bar{x}$ = 0.1% for reptiles, and $\bar{x}$ = 0.2% for arthropods). A cumulative plot of diet frequencies (Figure 5.1a) indicates that 90% of an "average" Mexican spotted owl diet would contain 30% woodrats; 28% peromyscid mice; 13% arthropods; 9% microtine voles; 5% birds; and 4% medium-sized rodents, mostly diurnal sciurids. A cumulative plot of diet biomass (Figure 5.1b) indicates that, on average, 90% of a Mexican spotted owl diet is comprised of 53% woodrats; 13% rabbits; 9% peromyscid mice; 9% birds; and 6% medium-sized mammals such as diurnal sciurids. These rangewide patterns, however, are not consistent among RUs.

To evaluate geographic variation of Mexican spotted owl food habits, we examined diet data by recovery unit. Frequencies of prey were treated as binomial, either the prey species being compared was consumed during a successful foraging event or some other species was consumed. We transformed these data for parametric analyses using an arcsine-squareroot transformation (Freeman and Tukey 1950) and tested the hypothesis of no difference in diets among RUs using a one-way analysis of variance (ANOVA). A Tukey's test was used to conduct multiple comparisons among RUs when the ANOVA was significant. We conducted the tests for each of the 11 prey groups separately. We did not conduct an ANOVA on percent biomass estimates because these data were comprised of both frequency and prey mass, and our estimates of mass for prey were not significantly different among RUs except for voles (F = 4.4, d.f. = 6, 15, P = 0.009). Thus, prey mass would have been roughly equivalent among RUs and comparisons of percent biomass would have been equivalent to those of relative frequency.

Our analyses indicated significant differences in Mexican spotted owl diets among geographic location (Figure 5.2). Woodrats were taken more often in the Colorado Plateau compared to the Upper Gila Mountains and Sierra Madre Occidentalis - Norte (F = 4.6, d.f. = 6, 18, P = 0.005; Figure 5.2a). Voles were consumed more frequently by owls in the Basin and Range - East, Southern Rocky Mountains - Colorado, and Upper Gila Mountains RUs than in the Colorado Plateau and Basin and Range - West RUs (F = 8.3, d.f. = 6, 18, P < 0.001; Figure 5.2a). Pocket gophers were eaten more often in the Upper Gila Mountains compared to the Colorado Plateau (F = 4.5, d.f. = 6, 18, P = 0.006; Figure 5.2c); and birds were consumed more often by owls in the Southern Rocky Mountains - New Mexico, Basin and Range - West, and Upper Gila Mountains RUs than in the Colorado Plateau (F = 5.8, d.f. = 6, 18, P = 0.002; Figure 5.2d). Bats and reptiles were consumed more frequently in the Basin and Range - West RU compared to the Upper Gila Mountains RU (F = 2.9, d.f. = 6, 18, P = 0.038; Figure 5.2e and F = 3.3, d.f. = 6, 18, P = 0.024; Figure 5.2f, respectively). Of the five groups that did not differ significantly among RUs (peromyscid mice, rabbits, other small mammals, other medium mammals, and arthropods), only peromyscid mice ($\bar{x}$ = 27.2%, cv = 42% among units) and arthropods ($\bar{x}$ = 13.8%, cv = 70%) were frequent food items.

Interregional trends in prey consumption could be attributed to other factors like temporal variation in the owl's diet within each study area, or because the breeding status of owls differed among studies. Diet frequencies from each study were pooled across years and owl pairs regardless of reproductive status because this information was unavailable in most cases. However, the year in which diet samples were collected and the reproductive success of a sufficient number of owls were known for three studies (SACMT2, GILADM, COCODM). These three data sets were collected from two of the RUs, Basin and Range - East (SACMT2; Tables 5.3 and 5.6) and Upper Gila Mountains (GILADM, COCODM;

Table 5.7. Animal species consumed by Mexican spotted owls as determined from examination of 25 data sets collected from 18 geographic areas.

MAMMALS

Insectivora
Desert shrew *Notiosorex crawfordi*
Vagrant shrew *Sorex vagrans*
Dusky shrew *Sorex monticolus*
Merriam's shrew *Sorex merriami*
Dwarf shrew *Sorex nanus*
Arizona shrew *Sorex arizonae*

Chiroptera
Pallid bat *Antrozous pallidus*
Silver-haired bat *Lasionycteris noctivagans*
Hoary bat *Lasiurus cinereus*
Big brown bat *Eptesicus fuscus*
American free-tailed bat *Tadarida brasiliensis*
Big free-tailed bat *Tadarida macrotis*
California myotis *Myotis californicus*
Fringed myotis *Myotis thysanodes*
Yuma myotis *Myotis yumanensis*
Arizona myotis *Myotis occultus*
Southwestern myotis *Myotis auriculus*
Long-eared myotis *Myotis evotis*
Cave myotis *Myotis velifer*
Spotted bat *Euderma maculatum*
Western pipistrelle *Pipistrellus hesperus*
Townsend's big-eared bat *Plecotus townsendii*

Carnivora
Long tailed weasel *Mustela frenata*
Short-tailed weasel *Mustela erminea*

Lagomorpha
Eastern cottontail *Sylvilagus floridanus*
Black-tailed jack rabbit *Lepus californicus*

Rodentia
Ord's kangaroo rat *Dipodomys ordii*
Pocket mouse *Perognathus* sp
Botta's pocket gopher *Thomomys bottae*
Northern pocket gopher *Thomomys talpoides*
Southern pocket gopher *Thomomys umbrinus*
Gray-footed chipmunk *Tamias canipes*
Least chipmunk *Tamias minimus*
Rock squirrel *Spermophilus variegatus*
Thirteen-lined ground squirrel *S. tridecemlineatus*
Red tree squirrel *Tamiasciurus hudsonicus*
Southern flying squirrel *Glaucomys volans*
Abert's squirrel *Sciurus aberti*
Western harvest mouse *Reithrodontomys megalotis*
Deer mouse *Peromyscus maniculatus*
Brush mouse *Peromyscus boylii*
Rock mouse *Peromyscus difficilis*
Mexican woodrat *Neotoma mexicana*
White-throated woodrat *Neotoma albigula*
Bushy-tailed woodrat *Neotoma cinerea*
Desert woodrat *Neotoma lepida*
Yellow-nosed cotton rat *Sigmodon ochrognathus*
Mexican vole *Microtus mexicanus*
Long-tailed vole *Microtus longicaudus*
Meadow vole *Microtus pennsylvanicus*
Montain vole *Microtus montanus*
Mountain phenacomys *Phenacomys intermedius*
House mouse *Mus musculus*

BIRDS

Galliformes
Montezuma quail *Cyrtonyx montezumae*

Strigiformes
Northern pygmy-owl *Glaucidium gnoma*
Northern Saw-whet owl *Aegolius acadicus*
Flammulated owl *Otus flammeolus*
Elf owl *Micrathene whitneyi*

Apodiformes
White-throated swift *Aeronautes saxatalis*

Piciformes
Williamson's sapsucker *Sphyrapicus thyroideus*
Northern flicker *Colaptes auratus*

Passeriformes
Pinyon jay *Gymnorhinus cyanocephalus*
Steller's jay *Cyanocitta stelleri*
Gray jay *Perisoreus canadensis*
Gray-breasted jay *Aphelocoma ultramarina*
Rufous-sided towhee *Pipilo erythrophthalmus*
Black-headed grosbeak *Pheucticus melanocephalus*
Hepatic tanager *Piranga flava*
Western tanager *Piranga ludoviciana*
American robin *Turdus migratorius*
Hermit thrush *Catharus guttatus*
Painted redstart *Myioborus pictus*
Cowbird *Molothrus* sp.
Pine siskin *Carduelis pinus*
Warbling vireo *Vireo gilvus*
White-throated sparrow *Zonotrichia albicollis*
Finch *Carpodacus* sp.

REPTILES

Short-horned lizard *Phrynosoma douglassii*
Mountain spiny lizard *Sceloporus jarrovii*

ARTHROPODS

Scorpion *Vejovis* sp
Beetle *Orizabus* sp
Prionus beetle *Prionus heroicus*
Pine-boring beetle *Ergates spiculatus*
Pine scarab beetle *Plusiotis lecontei*
Oak scarab beetle *Plusiotis beyeri*
Rhinoceros beetle *Dynastes tityus*
Long-horned beetle *Derobrachus* sp
Dark june beetle *Diplotaxis* sp
Spotted sawyer beetle *Monochamus* sp
Line june beetle *Phyllophaga* sp
New Mexican camel cricket *Stracoceles neomexicana*
Potato bug *opelmatus fuscus*
Field crick *llus* sp
Orchard cicad *latypedia* sp
Owlet moth *Noctudiae*

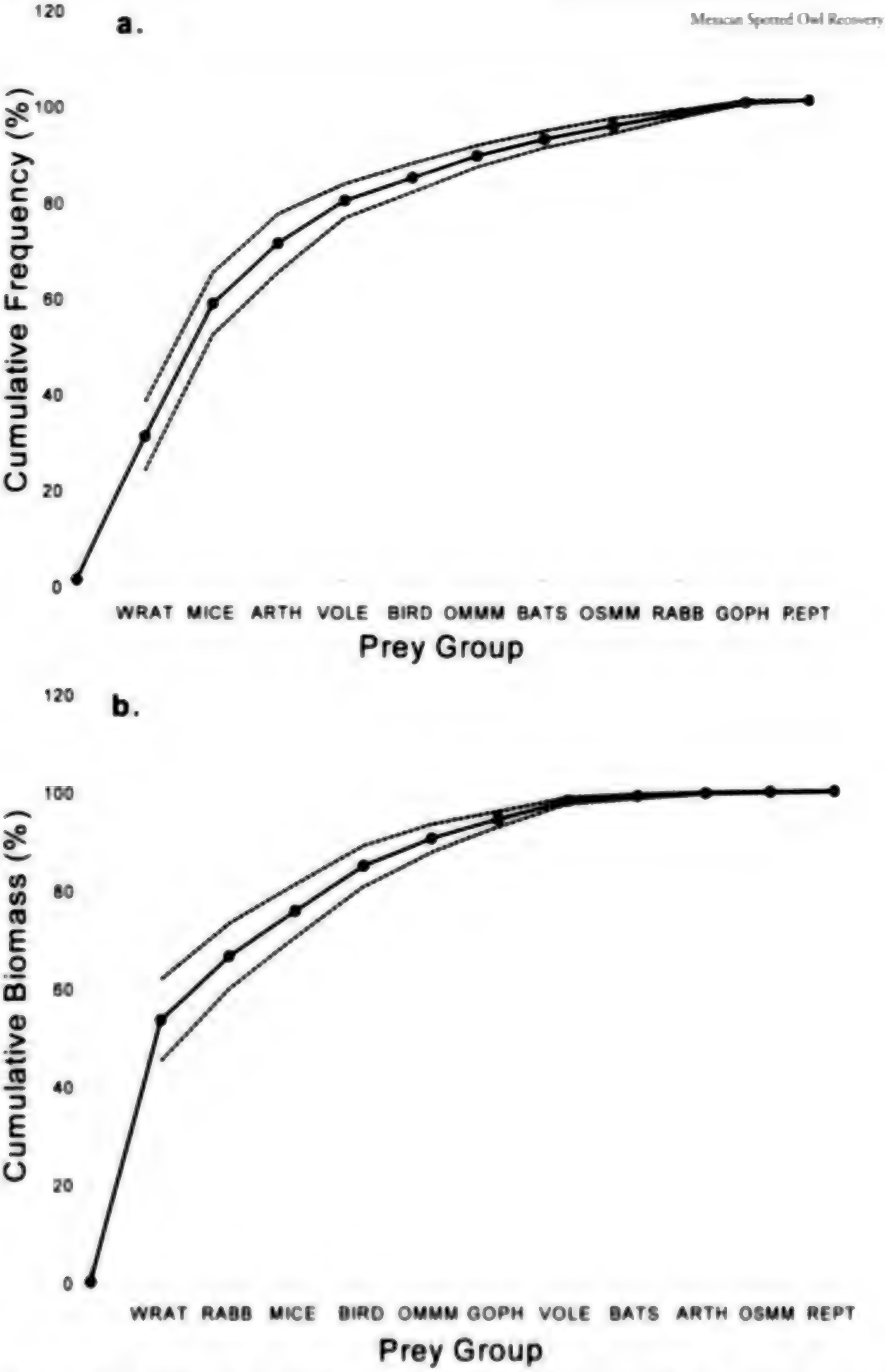

Figure 5.1. Cumulative distributions of prey in the diet of Mexican spotted owls presented as (**a**) relative frequency (%) of items and (**b**) percent biomass. Values are averages across 25 data sets conducted throughout the owl's range and dashed lines are 95% confidence limits. Prey groups are WRAT-woodrats; MICE-peromyscid mice; ARTH-arthropods; VOLE-voles; BIRD-birds; OMMM-other medium-sized mammals; BATS-bats; OSMM-other small-sized mammals; RABB-rabbits; GOPH-gophers; REPT-reptiles.

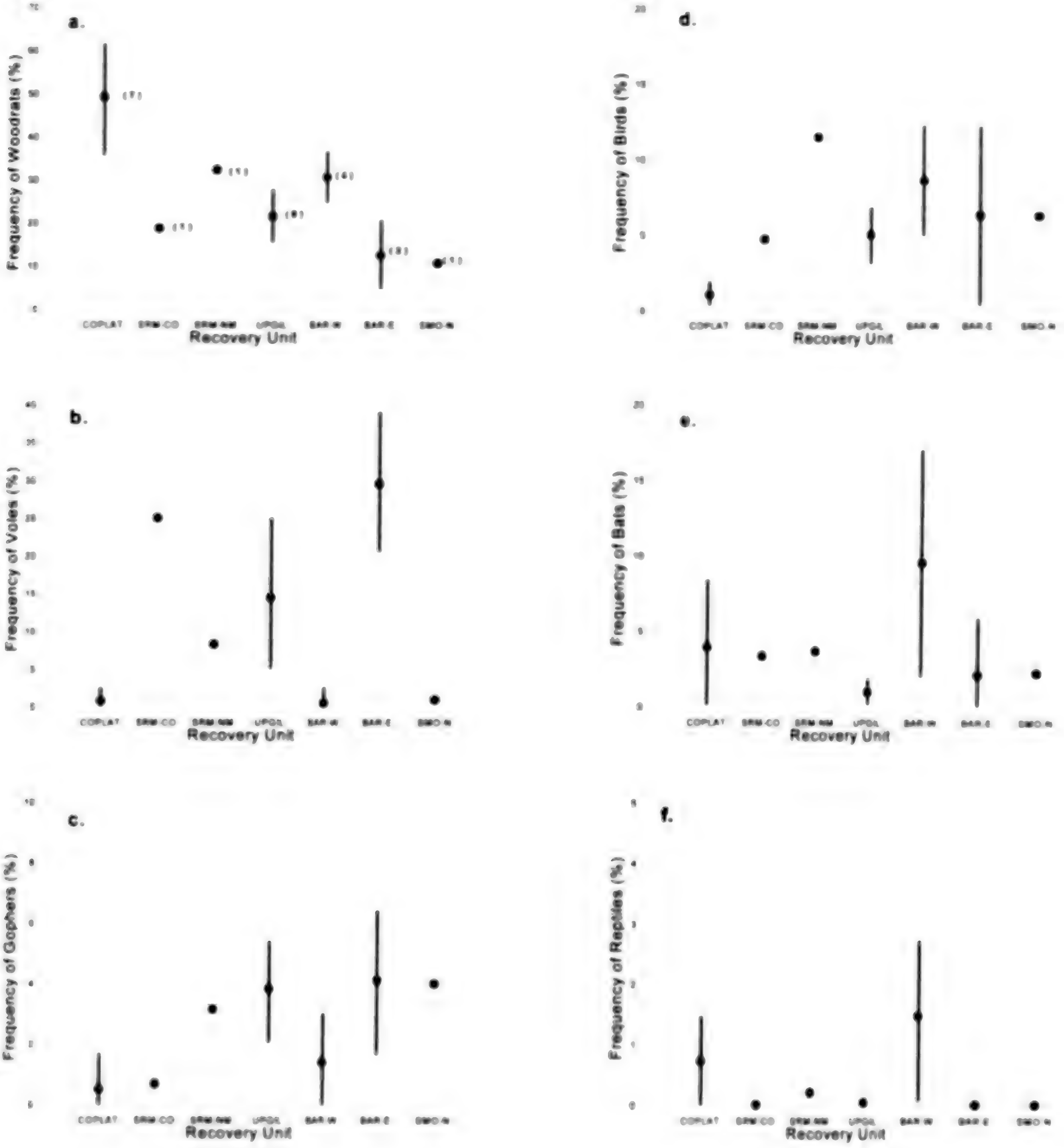

Figure 5.2. Geographic variability in the food habits of Mexican spotted owls presented as relative frequencies of (**a**) woodrats, (**b**) voles, (**c**) gophers, (**d**) birds, (**e**) bats, and (**f**) reptiles. Point values are from single studies or averages among the number of data sets shown in parenthesis. Vertical bars are 95% confidence intervals showing sampling and inter-data set variation within a recovery unit. Recovery Unit acronyms are COPLAT-Colorado Plateau; SRM-CO-Southern Rocky Mountains - Colorado; SRM-NM-Southern Rocky Mountains - New Mexico; UPGIL-Upper Gila Mountains; BAR-W-Basin and Range - West; BAR-E-Basin and Range - East; and SMO-N-Sierra Madre Occidental - Norte.

Tables 5.2 and 5.5). Owl reproductive success was determined similarly in all three studies using methods described by Forsman (1983). We used data from these studies to evaluate the influence of geography, time, and owl reproductive status on the interregional trends in the owl's diet.

To quantify the effect of these three factors, we analyzed the differences in relative frequency of a given prey group in the owl's diet among study area (SACMT2, COCODM, or GILADM; geographic variation), year (1991-1993; temporal variation), and number of owl young produced (0, 1, 2, or 3; variation in owl reproductive status) using a three-factor ANOVA. Prey groups that were common to owls in any of the three study areas were analyzed separately (woodrats, peromyscid mice, voles, pocket gophers, rabbits, other medium-sized mammals, and arthropods). We define common prey arbitrarily as those species contributing >10% of diet frequency or biomass, which includes the majority of species identified in the 90% cumulative averages (Figure 5.1). Statistical significance of each factor was used to quantify the importance of these factors in determining regional diet trends.

In 3 of 7 tests, consumption of common prey varied primarily by geographic location (Table 5.8). In the other 4 tests, consumption of woodrats, peromyscid mice, medium-sized mammals, and arthropods was influenced by an interaction between geographic location and year. However, significance values indicated that the consumption of woodrats and arthropods was influenced more by the owls' location than the particular year (Table 5.8). Prevalence of geographic variation in the three-factor ANOVA results supports our claims that the owl's feeding habitats differ among regions, as discussed above (Figure 5.2).

Diet differences of the Mexican spotted owl likely result from a combination of habitat differences among RUs for both the owl and its prey (See Zoogeography and Macrohabitats of Common Prey). Landscape approaches to management that maintain conditions for common prey of any predator are assumed to have beneficial effects (Reynolds et al. 1992). However, the reliability of such conservation strategies must be firmly based on ecological links among prey, predator, and environmental conditions. Thus, it is crucial to consider relationships among prey abundance and persistence of owl populations, and among prey abundance, availability, and habitat conditions.

RELATIVE IMPORTANCE OF PREY

Prey that positively influences owl survival, reproduction, or numbers may increase the likelihood of persistence of Mexican spotted owl populations. Although no information is available to quantify effects of food on spotted owl survival and density, previous studies have examined correlates between this owl's diet and reproduction. For example, Barrows (1987) suggested that larger prey (e.g., woodrats) was taken in greater frequency by owls with young. Thrailkill and Bias (1989) reported a similar pattern for California spotted owls occurring in the central Sierra Nevada. In contrast, Ward (1990) observed a different pattern for northern spotted owls in northwestern California. He found that large prey was taken in relatively equal frequency by breeding and nonbreeding owls, presumably because woodrats were a common food resource for owls regardless of breeding status. These different results may reflect variation in prey availability, sampling bias and variation, temporal variation, or true regional differences in owl diets.

To evaluate if any particular prey group could increase persistence of the Mexican spotted owl, we analyzed owl reproductive success (average number of young fledged) as a function of diet, year, and geographic location using a three-factor ANOVA. This approach would allow us to quantify variation in owl reproduction that could be attributed to the frequency of a particular prey in the owl's diet.

[illegible] reproduction related to consumption frequency of a given prey group would imply a relative importance of that prey. In using this approach, we further assumed that prey species that were positively related to reproduction also enhanced the owl's survival.

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Table 5.8. Factors influencing trends observed in Mexican spotted owl diets. Data are from three studies conducted in northern Arizona, the Sacramento Mountains, New Mexico, and the Tularosa Mountains, New Mexico, during breeding seasons of 1991, 1992, and 1993.

	Woodrats			**Peromyscid Mice**			**Voles**			**Pocket Gophers**		
Source of Variation	(F	df1, df2	P)	(F	df1, df2	P)	(F	df1, df2	P)	(F	df1, df2	P)
Main effects	5.625	7, 88	0.000	5.512	7, 88	0.000	10.041	7, 88	0.000	1.885	7, 88	0.081
Study area	11.599	2, 88	0.000	6.305	2, 88	0.003	30.125	2, 88	0.000	4.939	2, 88	0.009
Year	6.040	2, 88	0.003	8.247	2, 88	0.001	3.210	2, 88	0.045	0.626	2, 88	0.537
No. of owl young	2.140	3, 88	0.101	4.130	3, 88	0.009	0.484	3, 88	0.694	1.526	3, 88	0.213
Two-way interactions	1.451	16, 88	0.137	1.896	16, 88	0.031	0.722	16, 88	0.764	1.132	16, 88	0.340
Area x year	2.854	4, 88	0.028	3.492	4, 88	0.011	1.088	4, 88	0.367	0.875	4, 88	0.482
Area x young	1.461	6, 88	0.201	0.216	6, 88	0.971	0.535	6, 88	0.780	0.874	6, 88	0.517
Year x young	2.166	6, 88	0.054	0.893	6, 88	0.504	0.715	6, 88	0.638	1.165	6, 88	0.263
Three-way interactions												
Area x year x young	1.760	9, 88	0.087	1.109	9, 88	0.365	0.430	9, 88	0.916	0.737	6, 88	0.674
Explained	2.451	32, 88	0.001	2.466	32, 88	0.000	2.679	32, 88	0.000	1.186	32, 88	0.263
Residual (Mean square, df)	0.014	88		0.035	88		0.075	88		0.012	88	
Total (Mean square, df)	0.019	120		0.049	120		0.037	120		0.012	120	

Table 5.8. (continued)

	Rabbits			Other Medium Mammals			Arthropods		
Source of Variation	(*F*	df1, df2	*P*)	(*F*	df1, df2	*P*)	(*F*	df1, df2	*P*)
Main effects	4.224	7, 88	0.000	1.039	7, 88	0.610	4.542	7, 88	0.000
Study area	11.447	2, 88	0.000	0.148	2, 88	0.863	4.606	2, 88	0.013
Year	1.233	2, 88	0.296	1.766	2, 88	0.177	3.900	2, 88	0.024
No. of owl young	1.114	3, 88	0.348	1.054	3, 88	0.373	3.089	3, 88	0.031
Two-way interactions	1.162	16, 88	0.314	2.579	16, 88	0.005	2.144	16, 88	0.013
Area x year	1.874	4, 88	0.122	4.870	4, 88	0.001	3.287	4, 88	0.015
Area x young	0.316	6, 88	0.927	0.570	6, 88	0.753	1.281	6, 88	0.274
Year x young	1.152	6, 88	0.351	0.673	6, 88	0.671	1.650	6, 88	0.143
Three-way interactions									
Area x year x young	0.595	9, 88	0.798	0.557	9, 88	0.829	1.560	9, 88	0.160
Explained	1.672	32, 88	0.031	1.573	32, 88	0.050	2.505	32, 88	0.000
Residual (Mean square, df)	0.009	88		0.020	88		0.030	88	
Total (Mean square, df)	0.010	120		0.023	120		0.043	120	

This analysis was conducted by stratifying and comparing variation in the number of young owls produced among three study areas (SACMT2, COCODM, GILADM), three different breeding seasons (1991-1993), and three amounts of prey consumption, low (< 33%), high (≥ 66%), or medium. Seven prey groups were examined in separate ANOVAs to ensure independence among diet frequencies. These included woodrats, peromyscid mice, voles, gophers, rabbits, other medium-sized mammals, and arthropods. Study area and year were included as blocking factors to account for spatial and temporal effects that might alternatively explain patterns in the owl's reproduction, respectively. This analysis differed from the 3-factor ANOVA used to examine geographic variation in the owl's diet where number of young was treated as a predictor variable rather than a response.

Results from each ANOVA suggested that the owl's reproductive success was not influenced by a single prey species but rather by many species in combination. None of the specific prey groups significantly influenced owl reproductive success when diet frequencies were examined separately (Table 5.9). Time was a significant factor influencing the owl's reproduction (Table 5.9) when consumption of woodrats or voles was examined. Prey abundance is known to fluctuate through time. Thus, effects attributed to temporal variation may also represent associated changes in prey populations. However, it is more likely that the owl's reproductive success was influenced by total prey biomass consumed in a given year, rather than by a single prey species. For example, when frequencies of the three most common prey groups, woodrats, peromyscid mice and voles were combined and analyzed, diet was a nearly significant predictor of the owl's reproductive success ($F = 2.930$, d.f. = 2, 98, $P = 0.058$). More owl young were produced when moderate to high amounts of these common prey were consumed in all three study areas (Figure 5.3).

Contrary to the above results, certain prey species may be more important in certain regions of the owl's range. For example, other information from Ward et al. (unpublished) suggests that reproductive success of Mexican spotted owls in the Sacramento Mountains may increase when deer mice populations irrupt. In 1991, deer mouse biomass averaged 0.911 kg/ha in mixed-conifer forests (Figure 5.4a) and the number of young produced corresponded to the number of peromyscid mice consumed (Figure 5.4b). In 1992 and 1993, owl reproductive success decreased corresponding with a reduction in deer mouse abundance and the frequency of peromyscid mice consumed by owls (Figure 5.4c). Reproduction among owls dwelling in steep-walled canyons of the Colorado Plateau may also depend on a specialized diet because these owls consume a greater number of woodrats compared to other localities (Table 5.1). These results may be exceptions, as most of our findings support maintenance of several common prey species, rather than enhancing populations of a few.

ZOOGEOGRAPHY AND MACROHABITATS OF COMMON PREY

As detailed earlier, Mexican spotted owls use a variety of prey. Species regarded as "common" are those comprising ≥10% of the owl diet by relative frequency or biomass within a given RU. Prey commonly consumed by the owl varies geographically (Table 5.10). This geographic variation can be attributed to two primary factors: the geographic range of the prey and the degree of sympatry in macrohabitats of the owl and its prey. Below, we provide an overview of basic macrohabitat associations of common owl prey.

MAMMALS

Bats

As a group, bats are common prey in portions of the Colorado Plateau, Upper Gila Mountains, and Basin and Range - West RUs and they are consumed occasionally by owls in all RUs. If taken from outside roosts or nursery colonies, bats may represent a low-cost, opportunistic food source for the owls. No particular species appears to be used in great abundance; but when considered as a group, the importance

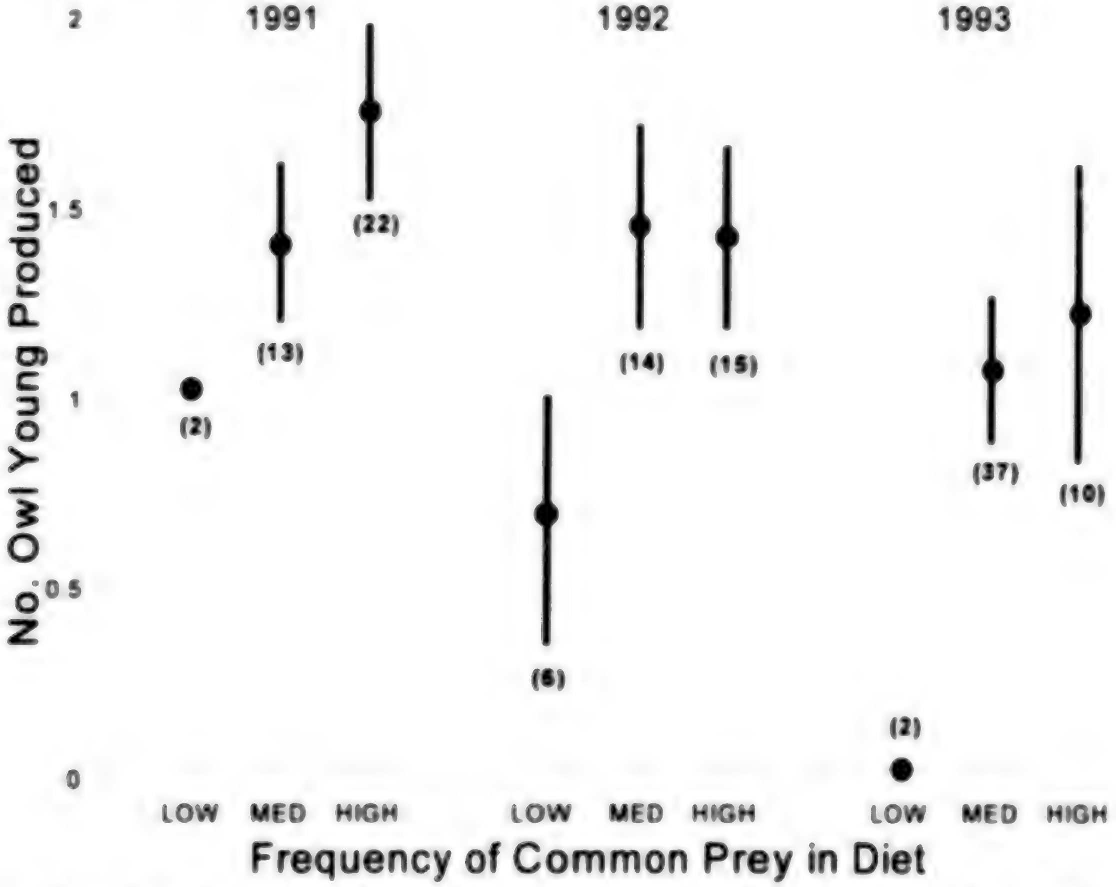
Table 5.9. Factors influencing production of Mexican spotted owls in northern Arizona, the Sacramento Mountains, New Mexico, and the Tularosa Mountains, New Mexico, during 1991, 1992, and 1993. Consumption of common prey was categorized according to the frequency of that prey in the owls' diet: low (<33%), medium (33% - 65.9%), and high (≥ 66%). Higher order interactions of effects were nonsignificant ($P > 0.05$) in tests on peromyscid mice or could not be quantified in tests with other prey because of limited sample sizes.

	Woodrats			Peromyscid Mice			Voles			Pocket Gophers		
Source of Variation	(F	df1, df2	P)	(F	df1, df2	P)	(F	df1, df2	P)	(F	df1, df2	P)
Main effects	1.472	5, 115	0.204	1.805	6, 98	0.106	1.514	5, 115	0.191	1.311	5, 115	0.264
Study area	0.250	2, 115	0.770	0.098	2, 98	0.907	0.591	2, 115	0.555	0.166	2, 115	0.847
Year	3.117	2, 115	0.048	1.411	2, 98	0.249	3.863	2, 115	0.074	2.536	2, 115	0.084
Prey consumption	2.160	1, 115	0.176	2.719	2, 98	0.071	2.273	1, 115	0.135	1.082	1, 115	0.301
Explained	1.472	5, 115	0.204	0.991	22, 98	0.482	1.514	5, 115	0.191	1.311	5, 115	0.264
Residual (Mean square, df)	1.111	115		1.135	98		1.110	115		1.119	115	
Total (Mean square, df)	1.133	120		1.133	120		1.133	120		1.133	120	

Table 5.9. (continued)

	Rabbits			Other Medium Mammals			Arthropods		
Source of Variation	(*F*	df1, df2	*P*)	(*F*	df1, df2	*P*)	(*F*	df1, df2	*P*)
Main effects	1.207	5, 115	0.310	1.293	5, 115	0.272	1.606	6, 114	0.152
Study area	0.177	2, 115	0.838	0.198	2, 115	0.820	0.249	2, 114	0.780
Year	2.764	2, 115	0.067	2.980	2, 115	0.055	2.897	2, 114	0.059
Prey Consumption	0.584	1, 115	0.446	0.997	1, 115	0.320	2.034	2, 114	0.135
Explained	1.207	5, 115	0.310	1.293	5, 115	0.272	1.606	6, 114	0.152
Residual (Mean square, df)	1.124	115		1.120	115		1.100	114	
Total (Mean square, df)	1.133	120		1.133	120		1.133	120	

Figure 5.3. Reproductive success (mean number of young produced) as a function of low (<33%), medium (33-65.9%), or high (≥ 66%) consumption of woodrats, peromyscid mice, and voles, by Mexican spotted owls occurring in the Sacramento Mountains, New Mexico, northern Arizona, and Tularosa Mountains, New Mexico. Vertical bars are standard errors. Number of owl territories is shown in parentheses.



of bats to the owl may be considerable (Tables 5.7 and 5.10).

Bats occupy many macrohabitats, ranging from arid shrublands to spruce-fir forest. In particular, rock crevices and tree snags are commonly used for roosting and raising young. These microhabitat components often occur in habitats used by Mexican spotted owls for roosting and nesting.

Rabbits

Cottontail rabbits are common prey according to diet biomass for all RUs except in the Colorado Plateau (Table 5.10). Rabbits can provide a great amount (50 to 400 g; 1.8-14.1 oz) of food per captured individual. Desert and eastern cottontails are more commonly associated with xeric vegetation types such as pinyon-juniper and oak woodlands, although Ward (personal observation) has observed eastern cottontails within mixed-conifer forests of the Sacramento Mountains, New Mexico. Only scant information describes the specific habitat associations of cottontails in New Mexico. Hoffmeister (1986) notes that in Arizona both desert and eastern cottontails inhabit pinyon-juniper, whereas eastern cottontails also use oak woodland. Typically, these habitats are relatively open with a well developed grass understory. In contrast, Nuttall's cottontails are found in more mesic grassy or rocky areas near pine, pine-oak, mixed-conifer, and spruce-fir forests in the northern portion of the owl's range.

Pocket Gophers

Pocket gophers are common prey within the Basin and Range - West and Upper Gila Mountains RUs. Pocket gophers typically inhabit meadows and meadow edges, although they also

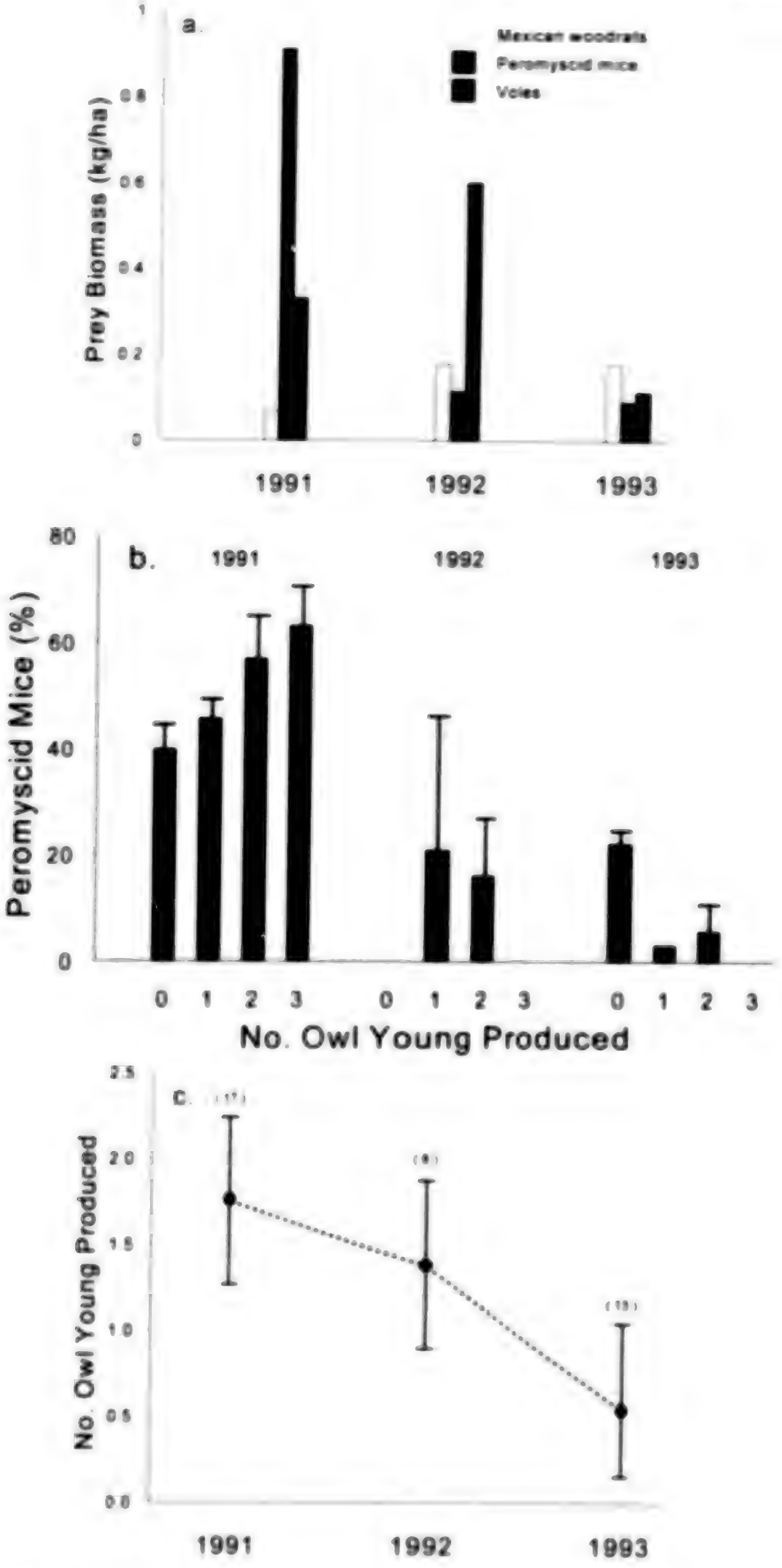


Figure 5.4. Biomass (kg/ha) of (**a**) common prey occurring in mixed-conifer forests, (**b**) frequencies of peromyscid mice consumed by Mexican spotted owls stratified by number of owl young produced, and (**c**) average (±95% CI) number of owl young produced in the Sacramento Mountains, New Mexico (Ward et al. unpublished). Bars in (**b**) represent variation among owl pairs (standard errors).

Table 5.10. Prey comprising ≥10% of relative frequency (X) or biomass (O) in the diet of Mexican spotted owls.

Prey Group	Colorado Plateau	Southern Rocky Mountains - Colorado	Southern Rocky Mountains - New Mexico	Upper Gila Mountains	Basin & Range - West	Basin & Range - East	Sierra Madre Occidental - Norte
Bats	X			X	X		
Rabbits	O	O	O	O	O	O	O
Pocket Gophers				O			O
Peromyscid Mice							
Deer mouse	X O	X O	X	X O	X O	X O	X O
Brush mouse	X O	X O	X	X O	X O	X O	
Canyon mouse	? ?						
Woodrats							
Mexican woodrat	X O	X O	X O	X O	X O	X O	X O
Bushy-tailed woodrat	X O	X O	X O				
Desert woodrat	X O				X O		
White-throated woodrat		X O	X O				
Voles							
Mexican vole		X O		X O		X O	
Mountain vole		X O	X O				
Meadow vole		X O	X O				
Long-tailed vole		X O		X O		X O	
Birds			X O	X	X O	O	
Arthropods	X	? X	X	X	X	X	

Owl diets classified to prey genera likely include this species based on its distribution.

Undetermined

occur within woodlands and forests. Botta's pocket gopher, northern pocket gopher, and southern pocket gopher occur within the range of the Mexican spotted owl. Botta's pocket gopher is the most widespread, being found in most vegetation types. The northern pocket gopher occurs in montane habitats of the northern part of the owls' range. The southern pocket gopher is found in Basin and Range - West and Mexican RUs. Both Hoffmeister (1986) and Findley et al. (1975) noted that Botta's pocket gopher is ubiquitous whenever soil is suitable for burrowing, whereas the northern pocket gopher is more typically found in parks and meadows within montane forests. Findley et al. (1975) stated that the southern pocket gopher inhabits shallow, rocky soils of pine forests.

Peromyscid Mice

Eight peromyscid mice occur within the range of the Mexican spotted owl. Only two species, the deer mouse and brush mouse are consumed regularly by owls in all RUs (Table 5.10). A third species, the canyon mouse, is likely consumed by owls dwelling in the Colorado Plateau RU and the rock mouse has been reported in the diet of owls occurring in the Basin and Range - East RU (Table 5.7).

The deer mouse is widespread, inhabiting all vegetation types except high-elevation tundra (Bailey 1931, Hall and Kelson 1959, Armstrong 1977, Goodwin and Hungerford 1979). High reproductive success of spotted owls in the Sacramento Mountains, New Mexico, (Basin and Range - East RU) has been recorded during irruptions of deer mice in mixed-conifer forests (See Abundance and Distribution of Common Prey, Sacramento Mountains).

More restricted in distribution, the brush mouse typically inhabits areas with extensive rock and shrub cover in pinyon-juniper, riparian, oak, and pine-oak woodlands (Wilson 1968, Armstrong 1979, Svoboda et al. 1988). Goodwin and Hungerford (1979) found that brush mice inhabit rocky slopes in central Arizona's pine-oak forests, but rarely use pure stands of pine.

The canyon mouse occupies the canyon walls, cliffs, and steep rocky slopes of northern Arizona, Utah, northwestern New Mexico, and western Colorado (Armstrong 1979, Johnson and Armstrong 1987). Findley et al. (1975) reported that the canyon mouse is often found in pinyon-juniper woodlands at the base of cliffs, although Johnson and Armstrong (1987) noted that vegetation associations are of limited importance relative to the presence of suitable rocky substrates.

The rock mouse is found in association with rocky substrates generally above 1,900 m (6,230 ft) elevation (Findley et al. 1975, Cornely et al. 1981). This species occurs in most of the United States portion of the owl's range and is often sympatric with deer mice and brush mice (Wilson 1968, Cornely et al. 1981, Ribble and Samson 1987).

Woodrats

Mexican, bushy-tailed, desert, and white-throated woodrats are consumed by Mexican spotted owls. For the owl, woodrats provide a large mass of food per capture. This prey is a primary food source for owls through most of its range but particularly in the canyon habitats of the Colorado Plateau RU, where all four species of woodrats are sometimes found (Table 5.10).

The Mexican woodrat is perhaps the most common woodrat found within the range of the Mexican spotted owl. It occurs within all RUs, although populations are disjunct because of the species' montane distribution (Cornely and Baker 1986). The altitudinal range of the Mexican woodrat begins in the lower pine zone and extends upward through mixed-conifer forests where Findley et al. (1975) reported they reach their greatest abundance. Hoffmeister (1986; see also Goodwin and Hungerford 1979) regarded Mexican woodrats as rock dwellers within these vegetation types, infrequently extending into pinyon-juniper woodlands. Armstrong (1972), however, reported that this species typically uses pinyon-juniper woodland in western Colorado and scrub-like oaks and mountain mahogany vegetation along the eastern foothills northwards almost to Wyoming. The range of Mexican woodrats in Utah is restricted to the southeastern portion of the state, east of the Colorado River.

Presumably, the species uses similar habitats in Utah as it does in western Colorado.

Bushy-tailed woodrats are a common diet component within the Colorado Plateau and both Southern Rocky Mountain RUs. This species is a cordilleran mammal of western Colorado, northcentral and northwestern New Mexico, northeastern Arizona, and eastern Utah (Durrant 1952, Hoffmeister 1986, Findley et al. 1975, Armstrong 1972, 1979). Finley (1958) reported that bushy-tailed woodrats use a variety of vegetation types, primarily woodland and shrublands. Their distribution may depend on the presence of suitable rock outcrops rather than specific vegetation (Finley 1958, Hoffmeister 1986). At higher elevations, these outcrops interrupt open forests of Douglas-fir, aspen, or ponderosa pine containing a well-developed shrub understory. Typically, lower elevation sites are dominated by pinyon and juniper.

The desert woodrat is consumed by owls in the Colorado Plateau RU. This species is most abundant in the Arizona strip where it inhabits a variety of plant communities including creosote bush and cacti to junipers and pine (Hoffmeister 1986). Desert woodrats frequently nest in crevices of cliffs and rock outcrops within juniper or shadscale plant communities of Utah and Colorado, below 2,000 m (6,560 ft) elevation (Finley 1958).

White-throated woodrats are common prey of owls occurring in the Upper Gila Mountains and Basin and Range - West RUs and are less frequently consumed by owls in other RUs. This woodrat species is typically distributed below the conifer belt, although it can be found in pinyon-juniper woodlands (Hoffmeister 1986).

Voles

Four species of voles are common prey of the Mexican spotted owl including the Mexican (or Mogollon vole [after Frey and LaRue 1993]), mountain, meadow, and long-tailed voles (Table 5.10). Three of these species can be ordered along an environmental moisture gradient from semi-arid (Mexican vole), mesic (mountain vole), to hydric (meadow vole). Long-tailed voles inhabit environments along the entire gradient (Getz 1985).

The Mexican vole is common within the greatest number of RUs, including Basin and Range - East, Southern Rocky Mountains - New Mexico, and Upper Gila Mountains RUs. It is fairly widely distributed in Arizona and New Mexico, but it is confined to the southeast part of Utah and to southwest Colorado. This species occurs in the widest range of habitats of any microtine and is generally associated with xeric grassy locations extending from pinyon-juniper to spruce-fir zones (Armstrong 1972, Findley and Jones 1962, Findley et al. 1975, Finley et al. 1986, Hoffmeister 1986, Frey and LaRue 1993).

The two species associated with wet conditions (mountain and meadow voles) generally occur in the northern portion of the owl's range. Mountain voles are common prey in the Colorado Plateau and both Southern Rocky Mountain RUs. In these areas, the mountain vole occupies forest meadows ranging in elevation from open pine-oak to spruce-fir forests. Armstrong (1977) found mountain voles in dense grass cover with a sparse overstory. This vole's geographic range includes most montane regions along the north-south axes of Colorado and Utah, northern New Mexico, and the White Mountains in Arizona. Meadow voles occur in both Southern Rocky Mountains RUs where permanent water is provided by springs and marshes (Armstrong 1972, Findley et al. 1975, Finley et al. 1986).

The long-tailed vole occurs within the Southern Rocky Mountains - New Mexico, Upper Gila Mountains, and Basin and Range - East RUs. Findley et al. (1975) reported that it is associated with meadows and forest edge, being most common in the mixed-conifer and spruce-fir zones but also using mixed-conifer stringers found along canyons in the ponderosa pine zone. Armstrong (1972, 1977) noted that this microtine requires a grassy understory less than other vole species because it is often found within forests supporting minimal grass cover.

Birds

Birds are common prey for the owls in the Southern Rocky Mountains - New Mexico, Upper Gila Mountains, and Basin and Range - West RUs where numerous species have been identified in pellets (Table 5.7). The importance of birds to spotted owls is uncertain. Birds do contribute to the diversity of prey taken by owls and may provide food resources when small mammals are less abundant. However, use of birds as prey is likely seasonal because many of the passerine species consumed by owls are migratory. All species identified in the owls' diet to date are forest dwellers.

Arthropods

Arthropods are common prey of spotted owls in the Colorado Plateau, Southern Rocky Mountains - Colorado, Southern Rocky Mountains - New Mexico, and Upper Gila Mountains RUs. Many species are consumed (Table 5.7). The importance of arthropods to spotted owls is also uncertain. If one considers biomass alone, arthropods contribute little to the owl's diet. However, arthropods may provide a low cost, high quality food taken opportunistically. Description of macrohabitats of arthropods consumed by spotted owls is beyond the scope of this document. Active management of arthropod populations for owl recovery is probably not necessary.

ABUNDANCE AND DISTRIBUTION OF COMMON PREY

The availability of prey to Mexican spotted owls depends on prey abundance, the vulnerability of the prey to capture by the owl, and the probability that the owl and its prey occur in the same habitat. All of these factors vary by habitat condition. In addition, the amount of energy available to the owl will vary according to the type, size, and condition of the prey. Thus, it is useful to convert prey numbers into values that reflect energy input. Because rodents are the most common prey of the spotted owl, we assume that most of the difference in energy content among mammalian prey can be attributed to body mass.

Although no information exists on the vulnerability of different prey species to capture by Mexican spotted owls, estimates of common prey abundance and mass within several different vegetation communities are available from research conducted in northern Arizona (Block and Ganey, unpublished) and the Sacramento Mountains, New Mexico (Ward et al., unpublished). These two studies provide estimates of biomass and microhabitat associations (See Prey Habitat) for the owl's common prey in four different vegetation communities used by owls for foraging, ponderosa pine-Gambel oak, mixed-conifer, high-elevation meadows, and ponderosa pine-pinyon-juniper woodlands. The methods and results of both studies are briefly described below.

Northern Arizona

Methods

Small mammal populations were sampled using live-trapping and mark-recapture techniques from November 1990 through December 1992 within home ranges of five owl pairs. The purpose of the sampling was to estimate biomass of the owl's common prey and determine the prey's distribution. Common prey were determined from owl pellets collected during this study.

The study area consisted of ponderosa pine-Gambel oak forest, although each trapping grid was unique with respect to the relative composition and structure of the vegetation. Ancillary trapping was conducted within the winter range of two owls that migrated downward to pinyon-juniper woodland in the Verde Valley. This trapping was confined to five sets of smaller trapping grids (described below) for a total of 574 trap nights.

Trapping grids were randomly established at general foraging areas identified by radio telemetry (Ganey and Block, unpublished data). Traps were arrayed in 10 x 10 or 2 x 10 grids with 20-m (65.5 ft) spacings between stations. The

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larger grids were used to estimate both density and habitat correlates; the smaller grids were used only to assess habitat use by species (see Prey Habitat). Large Sherman live traps (size 8 x 9 x 23 cm [3 x 3.5 x 9 in]) were placed at each grid station; extra-large Sherman live traps (size 10 x 18 x 60 cm (4 x 4.5 x 15 in) were placed at alternate stations. Two sizes of traps were used to minimize the potential bias against capturing larger prey such as woodrats in the smaller traps.

Grids were trapped from 3-7 nights during each trapping session. Traps were left open during the day to sample diurnal sciurids. The goal was to continue trapping until 90% of all captures were recaptures to approach assumptions of population closure. This goal was typically reached between five and seven nights. During periods of inclement weather, however, we relaxed this goal to minimize trapping mortalities. Each grid was trapped for 5-7 sessions during the study. Total trapping effort was 49,911 trapnights (adjusted for closed and unoccupied, or otherwise unavailable traps). When an animal was captured, it was identified to species, weighed, and marked by toe clipping.

Abundance was estimated as the number of individuals per effective sampling area (ha) using closed population estimators (Program CAPTURE; Otis et al. 1978, White et al. 1982). Although the number of individuals captured at some grids during some seasons was insufficient for producing unbiased estimates, we considered the closed population estimators in Program CAPTURE more appropriate than minimum numbers alive per grid area. The former permitted estimating capture probabilities and sampling variances plus population size; the latter would not.

Biomass of common prey, expressed as kilograms per hectare (kg/ha), was calculated as a product of prey density and average mass. The delta method (Goodman 1960) was used to estimate the sampling variance of biomass from the variances associated with sampling prey density and mass.

General Distribution

The three primary prey species captured in ponderosa pine-Gambel oak forests were deer mouse, brush mouse, and Mexican woodrat. Other prey species captured included pinyon mouse, white-throated woodrat, Stephens' woodrat, Mexican vole, rock squirrel, gray-collared chipmunk, and cliff chipmunk. Brush mice and white-throated woodrats were captured with the greatest relative frequency in pinyon-juniper woodlands. The trapping efforts did not sample prey species such as pocket gophers, cottontail rabbits, birds, and arthropods. Further, only the three primary species were captured in sufficient numbers to permit density calculations or estimates of habitat correlates. Thus, our analyses of population size and habitat use address only these three species.

Population Abundance

The deer mouse was the most abundant species captured, followed by the brush mouse and Mexican woodrat. A seasonal trend of decreased prey biomass during winter was noted (Figure 5.5a). Prey abundance and biomass also varied by year (Figure 5.5a) and among owl territories (Block and Ganey, unpublished data).

Sacramento Mountains

Methods

The Sacramento Mountains are located in southcentral New Mexico. An investigation of the abundance and distribution of common mammalian prey began in 1991 and is ongoing (Ward et al., unpublished data). Common prey were determined from owl pellets collected during this study. Abundance was estimated among three general vegetation communities using mark-recapture methodology.

The three communities included mesic forests, xeric forests, and meadows. Mesic forests were a mixture of Douglas-fir, white fir, southwestern white pine, ponderosa pine, and Englemann spruce (i.e., mixed conifer). Meadows consisted of forbs and grasses and were

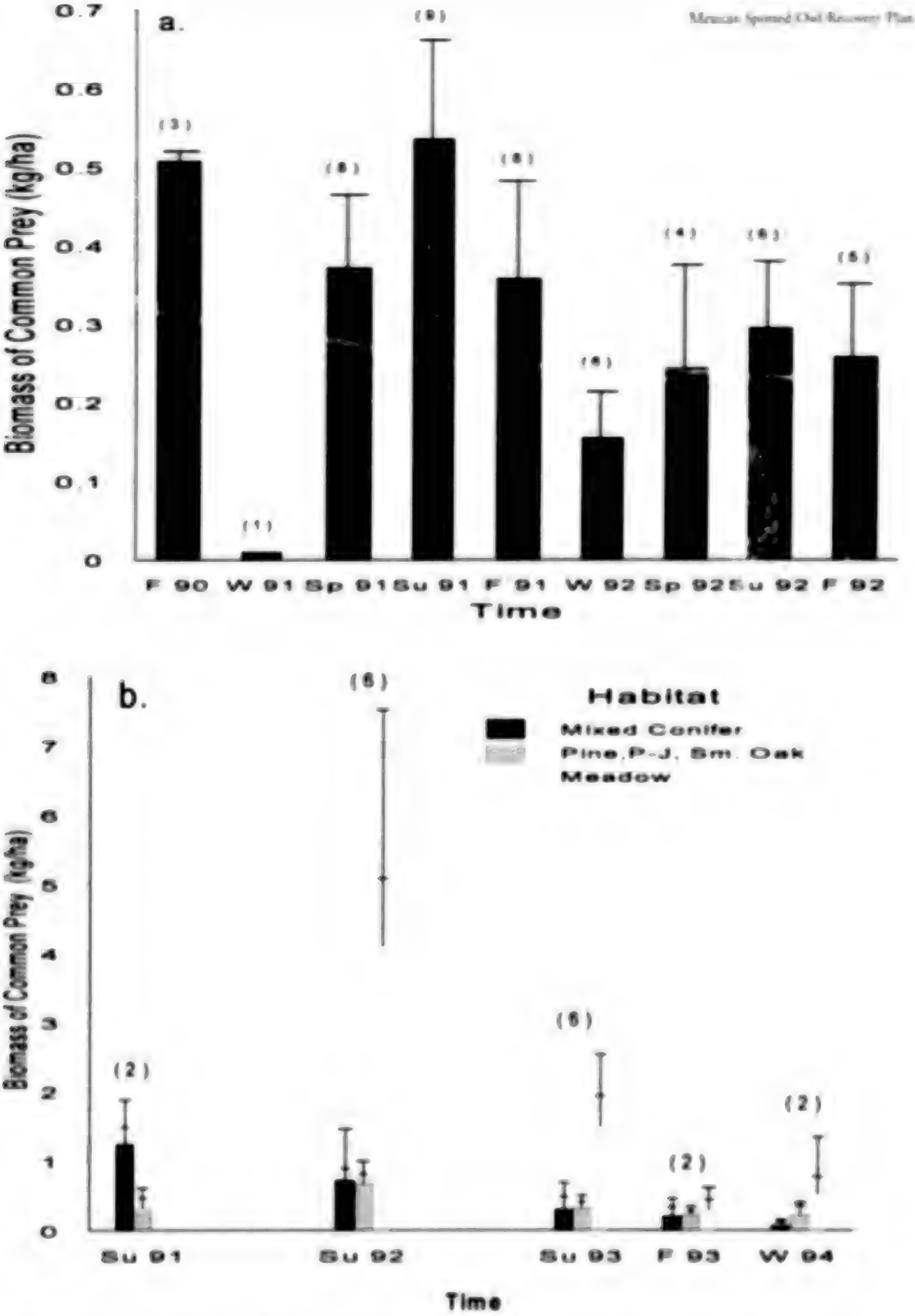

Figure 5.5. Average biomass of common prey (kg/ha) of the Mexican spotted owl in **(a)** pine-Gambel oak habitats of northern Arizona (Block and Ganey unpublished data) and **(b)** in three habitats of the Sacramento Mountains, New Mexico. Vertical bars are standard errors. Lower horizontal bars in **(b)** separate sampling error from errors associated with variation among sites. Number of sites within each habitat are shown in parenthesis.

associated with drainage bottoms adjacent to mesic forests. Xeric forests included ponderosa pine, pinyon, juniper, and low-growing oaks.

The same two sizes of live-traps described for the northern Arizona study were used to capture prey in the Sacramento Mountains. Traps were also arranged similarly, with the following exceptions. In 1991, four 13-ha (32.1-ac) trapping grids were established as part of a pilot study. Two grids were placed in the mesic forest and two in the xeric forest. In 1992 and subsequent years, six 4-ha (9.9-ac) trapping grids were placed in each of the mesic and xeric forest types. Traps were arrayed as 11 x 11 station grids. In addition, six 1.8-ha (4.5-ac) grids were established in meadows. Each of the latter grids consisted of 105 large Sherman traps spaced 15 m (49.2 ft) apart in a 5 x 21 array.

All grid sites were selected randomly from a list of known Mexican spotted owl territories. Grids were placed as close to a nest or roost area as possible while maintaining homogeneity at a scale analogous to a forest stand. In addition, each grid was ≤ 0.8 km (0.5 mi) from a nest or roost to ensure that the site was available for use by spotted owls.

All captured individuals were marked with uniquely numbered ear tags in both ears. Loss of both tags during an eight-night trapping session was less than 1% for all marked species. All other methods of sampling and data collection were similar to the study in northern Arizona (Block and Ganey, unpublished data). We therefore considered the results of both studies to be comparable. Prey abundance and biomass were estimated using the same procedures described for the northern Arizona study. Tests for spatial and temporal differences in prey biomass were conducted using a two-factor ANOVA.

General Distribution

Common prey included woodrats, peromyscid mice, voles, arthropods, cottontail rabbits, and other medium-sized mammals such as long-tailed weasels, red squirrels, and chipmunks (Tables 5.3 and 5.6). Cottontails and other medium-sized mammals were consumed infrequently but larger estimates of mass from a few individuals resulted in larger biomass calculations from these prey groups. However, the exact sizes of consumed individuals were undetermined and the range of mass for larger prey consumed by owls could have been considerable. For example, the size of a cottontail taken by a spotted owl could range 50 to 400 g (1.8-14.1 oz) whereas a peromyscid mouse could range 10 to 40 g (0.4 to 1.4 oz). This potentially results in upwardly biased estimates of biomass for larger species in the owls' diet. For this reason, we are uncertain about the role of cottontails and other medium-sized prey as common food resources for the owl. In contrast, arthropods comprised 11.4% of the diet but were not considered energetically important because of their small mass (1-2 g [0.04-0.07 oz]).

Five species common in the owl's diet were captured regularly during live-trapping. The distribution of each species varied by vegetation community. Deer mice were found in all three communities. Brush mice were restricted to the xeric forest type and were primarily associated with areas containing shrub-form oaks. Long-tailed voles and Mexican voles were more common in meadows, but they also occupied the transition zones between meadows and mesic forests. Mexican voles were also found infrequently in xeric forests. Mexican woodrats occupied mesic forests and the ecotone between these forests and meadows, as well as xeric forests. Medium-sized mammals such as the gray-footed chipmunk were found in mesic forests, the edges between mesic forests and meadows, and rarely in xeric forests. Cottontail rabbits and red squirrels were only encountered in mesic forests. However, our sampling procedures were inadequate for estimating abundance and distribution of these species and of arthropods.

Population Abundance

Total biomass (kg/ha) of five common prey (Figure 5.5b) varied annually over the three summers 1991-1993 ($F = 12.7$, d.f. = 2, 32, $P < 0.001$) and also seasonally during the summer-fall-winter period of 1993-1994 ($F = 17.0$, d.f. = 2, 21, $P < 0.001$). Fluctuations in prey biomass also varied by vegetation community during both annual ($F = 5.5$, d.f. = 2, 32,

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P = 0.009) and seasonal cycles (F = 5.8, d.f. = 2, 21, P = 0.010). The general trend was that prey biomass was moderately high during the summer (when owls feed their young) of 1991, peaking in 1992, then decreasing to moderate levels in 1993 (Figure 5.5b). Further, temporal trends differed by vegetation community. Prey biomass decreased in mesic forests and meadows over consecutive summers but increased then decreased in xeric forests during this same period (Figure 5.5b). This relationship was evident by a statistically significant interaction of vegetation community and year on prey biomass (F = 3.3, d.f. = 3, 32, P = 0.032). Whereas prey biomass pooled across all communities decreased from the summer to fall of 1993 before increasing slightly in the winter (Figure 5.5b), seasonal trends differed among communities (F = 17.0, d.f. = 2, 21, P < 0.001). These patterns also showed an interactive influence of season and vegetation community on prey biomass (F = 3.0, d.f. = 2, 21, P = 0.044). Thus, abundance of potential food resources for the Mexican spotted owl in the Sacramento Mountains are temporally variable and habitat dependent.

The variations in total prey biomass were also reflected in the population dynamics of different species (Figure 5.6a). For example, deer mice densities within mesic forests peaked in the summer of 1991 and declined through the summer of 1993 while maintaining low densities in the meadows (Figure 5.6b). Deer mice in xeric forests maintained lower, relatively stable densities that peaked in summer of 1992 (Figure 5.6c). In contrast, Mexican voles maintained low, stable populations in the mesic forests but increased dramatically in meadows and moderately in xeric forests in the summer of 1992 before crashing in both habitats during the summer of 1993 (Figure 5.6).

In summary, the two studies indicate that the owl's food resources are quite variable among vegetation communities and through time. Arranging the four vegetation communities examined in these two studies in descending amount of summer prey biomass indicates that meadows > mixed-conifer forest > ponderosa pine-pinyon-juniper-oak woodlands > ponderosa pine-Gambel oak forest. When considering other factors that influence the availability of prey, mixed-conifer forests likely provide the greatest amount of food during summer periods. Rearranging the same communities according to winter prey biomass indicates that meadows > ponderosa pine-pinyon-juniper-oak woodlands > ponderosa pine-Gambel oak forest > mixed-conifer forest. Accounting for the availability of prey, woodlands with a mixture of ponderosa pine, pinyon-juniper, and oaks provide more prey to owls during winter months than the other three communities. However, temporal peaks of prey cycles are not correlated among these communities. That is, when prey are abundant in mixed-conifer forest one year and low a subsequent year, an opposite pattern may occur in a different vegetation community. The asynchrony of abundance among prey species, vegetation communities, and time may provide a buffer against the effects of extreme oscillation in prey cycles. This implies maintaining a mixture of vegetation communities within the owl's foraging range.

Results of both studies also showed that the owl's food is most abundant during the summer when young are being raised. Decreases in prey biomass occur from late-fall through winter. Seasonal decreases, like these, are typical of small mammal populations. Unfortunately, explanations for fluctuations in small mammal populations are equally variable and include artificial random patterns in population data, weather changes, behavioral mechanisms, predation, and age-related effects on demographic processes (e.g. fecundity, dispersal; see reviews by Conley and Nichols 1978, Finerty 1980).

Although the reasons for seasonal declines in prey and their ramifications on the owl have not been quantified, conditions that increase winter food resources will likely improve conditions for the owl. For example, Hirons (1985) has shown that large body reserves of fat and protein are essential during incubation by female tawny owls for successful reproduction. Abundant prey populations during winter and early spring periods increase the likelihood of egg laying and decrease the rate of nest abandonment (Hirons 1985).

Obviously, there will be little recourse for enhancing prey populations if factors like precipitation, temperature, or amount of snow

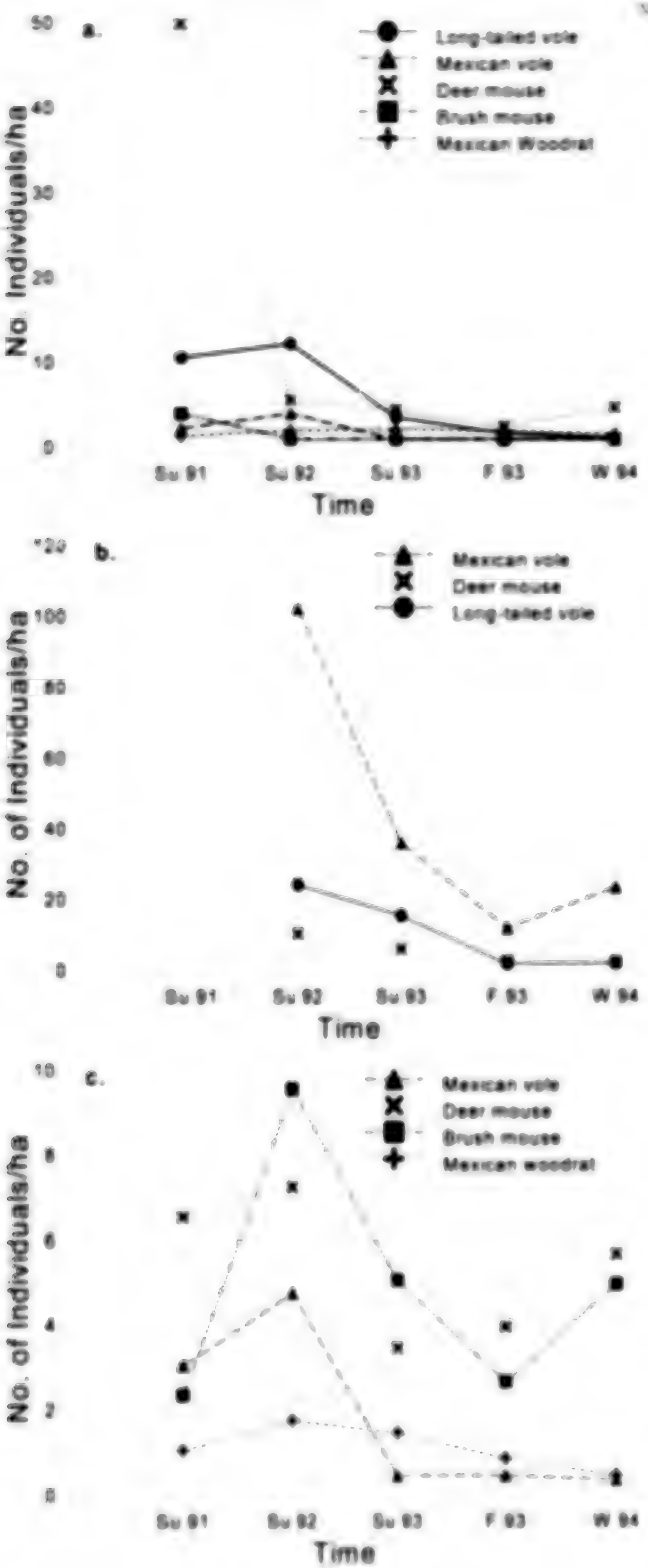

Figure 5.6. Trends in average density (no./ha) of common prey of the Mexican spotted owl in **(a)** mixed-conifer forest, **(b)** montane meadows, and **(c)** ponderosa pine-pinyon-juniper-oak woodlands, Sacramento Mountains, New Mexico. Summer (1992-93) values are based on 6 spatial replicates; summer (1991), fall, and winter values are based on 2 replicates.

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cover are the major causes of decline in prey populations. The degree to which habitat manipulation can ameliorate against weather effects or enhance prey availability requires investigation and is encouraged. Successful manipulation may provide a potent tool for recovering Mexican spotted owls or other predators in the future.

PREY HABITAT

Ensuring adequate food for the owl requires conserving and possibly restoring habitat of the owl's prey. Ideally, to succeed, those features of the environment that consistently cause increases in abundance and availability of desired prey species should be identified. In reality, few habitat studies are so revealing or precise (see Verner et al. 1986). However, habitat studies often do identify patterns and descriptive correlates of animal distribution or abundance. Although crude, this type of information frequently is all that is available for predicting the outcome of planning decisions or management prescriptions.

In the absence of cause-effect relationships among the owl's prey and its habitat, we present habitat correlates for the distribution of several common prey species. This information was determined from the same studies of prey abundance conducted in northern Arizona (Block and Ganey, unpublished data) and the Sacramento Mountains (Ward et al., unpublished data).

Northern Arizona - Pine-oak Forest

Field Methods and Statistical Analyses

Habitat-sampling plots were established as a 5-m [16.5-ft) radius centered at each trapping station (n = 1,260). Cover by grass, forbs, rock, dead woody debris of three size classes (<1 cm [0.34 in], 1-10 cm [0.39-3.9 in], >10 cm [3.9 in]), and live woody vegetation at four height strata (<1 m [3.3 ft], 1-2 m [3.3-6.6 ft], >2-5 m [6.6-16.4 ft], >5 m [16.4 ft]) were estimated as the percentage of 10 point intercepts (at 1-m [3.3 ft] intervals along a randomly oriented transect) covered by each of these variables. Tree diameters were measured with a dbh tape; heights were measured with a clinometer. Shrub and slash pile heights were measured with a meter stick. Mid-point diameters and lengths of logs within the plot were measured with a measuring tape. Numbers of trees and shrubs by species were recorded. Slope was measured with a clinometer and aspect with a compass.

Deer mice, brush mice, and Mexican woodrats were captured in sufficient numbers to permit habitat analyses. Stations where each species was captured were contrasted with those where it was not captured using analysis of variance with owl territory as a blocking factor. Two other analyses were also conducted. Logistic regression was used to examine differences between stations where each species was and was not captured that may not have been identified in the ANOVA. Stepwise multiple linear regression (Draper and Smith 1981) was used to evaluate relationships between small mammal population levels and habitat characteristics. The dependent variable was the number of trapping stations/grid where the species was captured. Independent variables were habitat characteristics aggregated across the grid.

Results

Deer mice used more open sites, on gentler slopes, and with less shrub and midstory canopy, smaller densities of Gambel oak trees and shrubs, but more slash piles and greater litter depth than stations where it was not captured (Table 5.11). In contrast, brush mice and Mexican woodrats both used sites characterized by greater slopes, low vegetation cover, sparser tree canopy (>5 m [16.4 ft]) cover, more Gambel oak shrubs, and greater log volume than areas where they were not captured (Table 5.11). Further, brush mice used areas with greater Gambel oak tree density and basal area and less ponderosa pine basal area than found at stations where it was not captured. Tree basal area at sites where Mexican woodrats were captured was significantly less and total rock cover was significantly greater than at sites where it was not captured.

Generally, results from logistic regression analyses corroborated results of the univariate analyses. Deer mice were associated with areas of

Table 5.11. Descriptive statistics (means with SE in parentheses) of selected habitat variables characterizing habitats of common mammalian prey of Mexican spotted owls (4 territories) in ponderosa pine-Gambel oak forests, northern Arizona, 1990-1992.

Variable	Deer Mouse			Brush Mouse			Mexican Woodrat		
	Capture stations[a] (*n* = 669)	P^1	P^2	Capture stations (*n* =295)	P	P	Capture stations (*n* =204)	P	P
Slope	15.0 (0.5)	<		21.8 (0.8)	>		19.6 (1.1)	>	
Cover (%)									
Grass	4.5 (0.3)			3.3 (0.4)	>		4.7 (0.6)		
Rock	21.8 (0.8)		**	28.1 (1.4)	<		30.2 (1.8)	>	
Down wood (<1 cm)	2.6 (0.3)			2.2 (0.4)			2.3 (0.4)		
Down wood (1-10 cm)	4.6 (0.3)			3.7 (0.4)	<		4.3 (0.6)		
Down wood (>10 cm)	2.5 (0.2)			2.3 (0.3)			3.0 (0.5)		
Vegetation (<1 m high)	5.6 (0.5)	<	**	13.1 (1.3)	>	*	17.0 (1.5)	>	*
Vegetation (1-2 m high)	6.4 (0.5)		**	12.8 (1.1)	>	**	12.9 (1.5)	>	**
Vegetation (2-5 m high)	14.2 (0.8)	<	**	24.3 (1.6)	>	**	20.4 (1.8)		**
Vegetation (>5 m high)	31.8 (1.2)		**	29.6 (1.8)	<		25.4 (2.1)		
Shrub density (#/plot)									
Gambel oak	3.0 (0.1)	<	**	5.4 (0.3)	>	**	5.2 (0.4)	>	**
Ponderosa pine	1.4 (0.1)		**	1.7 (0.2)		**	1.5 (0.2)		**
New Mexican locust	1.3 (0.1)			2.8 (0.2)	>	**	2.1 ([illegible])	>	
All species	6.0 (0.2)	<	**	10.5 (0.4)	>	**	9.3 (0.5)	>	**
Tree density (#/plot)									
Gambel oak	0.5 (0.1)	<		0.9 (0.2)	>		0.7 (0.1)		
Ponderosa pine	2.4 (0.1)			2.6 (0.2)		**	2.2 (0.2)		
All species	3.0 (0.1)			3.5 (0.3)			2.9 (0.2)		
Tree basal area (m^2/ha)									
Gambel oak	2.4 (0.3)			4.4 (0.8)	>		2.0 (0.[illegible]		
Ponderosa pine	15.2 (0.6)		**	11.9 (1.3)	<		12.2 (0.[illegible]		
All species	17.8 (0.7)		*	16.4 (1.5)			14.6 (1.0	<	
Log density (#/plot)	0.6 (0.0)		*	0.6 (0.1)			0.6 (0.1		
Log volume (m^3/ha)	15.7 (1.9)			27.3 (5.5)	>		27.9 (6.0	>	

Table 5.11. (continued)

	Deer Mouse			Brush Mouse			Mexican Woodrat		
Variable	Capture stations[a] (n = 669)	P[b]	P[c]	Capture stations (n = 295)	P	P	Capture stations (n = 204)	P	P
Slash piles (#/plot)	0.2 (0.0)	>		0.0 (0.1)	<		0.1 (0.0)		
Litter depth (mm)	20.7 (0.7)	<	**	23.8			20.6 (1.3)		

[a] Stations where the species was captured at least once.

[b] Comparisons of capture vs. noncapture stations. >, significantly greater ($P < 0.05$) at capture stations than noncapture stations; <, significantly less ($P < 0.05$) at capture stations than noncapture stations.

[c] Results of tests on territory effect. *, significantly different ($P < 0.05$) among territories; **, significantly different ($P < 0.05$) among territories.

little slope, Gambel oak, and mid-story (2-5 m [6.6-16.4 ft]) vegetation. Brush mice and Mexican woodrats used areas with greater shrub density, rock cover, log volume, and Gambel oak cover.

In the multiple regression analysis, no variable entered the model for deer mice, suggesting that it is a habitat generalist. Two variables, shrub density and grass height, entered the regression model for brush mice. These two variables alone explained >96% of the variation in the data set. For Mexican woodrats, shrub density and slope entered the model and explained >92% of the variation in numbers. Thus, both brush mice and Mexican woodrats were apparently more stenotypic in habitat than deer mice and closely associated with shrub cover provided by Gambel oak and New Mexican locust.

Sacramento Mountains

Field Methods and Statistical Analyses

Habitat characteristics were measured within circular plots of 5-m [16.4-ft] radius centered at about 80% of the trap stations (*n* = 1,416). Stations were stratified by vegetation community: mesic forest (*n* = 583), xeric forest (*n* = 578), and meadow (*n* = 255). Within each plot, methods similar to those described above were used with the following exception: tree basal area and density were estimated with a plotless method using 10- and 20-factor prisms rather than the plot methods used in the ponderosa pine-Gambel oak forest of northern Arizona. Also, cover of woody vegetation by height strata was not recorded in the Sacramento Mountains.

Deer mice, brush mice, Mexican woodrats, long-tailed voles, and Mexican voles were captured in sufficient numbers to permit habitat analyses. Statistical analyses for each species were done separately by vegetation community. Habitat characteristics of trap stations where a species was captured were contrasted with stations where they were not captured using Student's *t*-test. A random sample of unused stations equal to the number of used stations was selected to meet the assumption of equal sample size except for Mexican voles in meadows, which were captured at >75% of the trap stations. Consequently, a subset of used stations equal to the available number of unused stations was randomly selected (*n* = 62) for conducting the analysis. Logistic regression was also used to determine the relative value of variables in distinguishing between stations where the animal was and was not captured. This second analysis was used to detect other variables that might identify habitat correlates not identified by use of Student *t*-tests.

Results

Mesic Forests.—Microhabitat analyses were possible for deer mice, Mexican woodrats, and long-tailed and Mexican voles. Deer mice were captured in areas with little herbaceous cover and extensive exposed soil (Table 5.12). Results from the logistic regression indicated that deer mice used areas with less herbaceous cover and greater densities of live conifer trees. Mexican woodrats used areas that had greater shrub but less herbaceous cover (Table 5.13). Shrub cover was the only variable included in the stepwise logistic regression model of habitat use by Mexican woodrats. Long-tailed voles occurred in areas characterized by less slope, less tree cover and exposed soil but greater herbaceous cover, fewer stumps, greater shrub numbers, and fewer conifer snags (Table 5.14). According to the logistic regression model, long-tailed voles used areas with less exposed soil, greater shrub density, and less slope. Mexican voles used sites with less shrub, tree and exposed ground cover, greater herbaceous cover, fewer shrubs, fewer conifer seedlings and saplings, lower density and less basal area of deciduous trees (Table 5.15). Mexican voles used sites with less tree cover and lower deciduous tree density according to the logistic regression model.

Xeric Forests.—Habitat analyses were possible for deer mice, brush mice, Mexican woodrats, and Mexican voles. As in mesic forests, deer mice occupying xeric forests were captured in areas with more exposed soil than at noncapture stations (Table 5.12). In contrast with mesic forests, deer mice in xeric forests were

Table 5.12. Habitat characteristics used by deer mice in three vegetation communities of the Sacramento Mountains, New Mexico. Only those variables that differed significantly between trap stations where deer mice were and were not captured are reported.

Variable	Mesic Forest		Xeric Forest		Meadow	
	Random (n=155)	Used[a] (n=155)	Random (n=185)	Used[a] (n=185)	Random (n=40)	Used[a] (n=40)
Slope (degrees)	37.7 (1.1)	38.7 (1.1)	32.1 (0.6)	27.3 (0.7)***	15.8 (1.2)	21.5 (1.9)*
Herbaceous cover (%)	40.8 (2.6)	31.0 (2.3)**	36.7 (1.8)	33.7 (1.8)	95.0 (2.6)	87.3 (3.3)
Shrub cover (%)	26.8 (2.1)	22.5 (2.2)	15.4 (1.4)	19.6 (1.6)*	2.3 (1.0)	3.5 (1.9)
Rock cover (%)	3.7 (0.8)	5.0 (0.9)	30.3 (1.8)	21.7 (1.6)***	0.3 (0.3)	0.8 (0.4)
Bare ground (%)	54.5 (2.6)	62.6 (2.4)*	38.4 (2.0)	48.3 (1.8)***	2.0 (0.9)	9.3 (2.7)*
Litter depth (cm)	30.2 (1.7)	30.5 (1.6)	15.5 (1.0)	18.9 (1.2)*	8.5 (1.9)	3.0 (1.2)*
Grass-forb height (cm)	4.2 (0.5)	3.0 (0.4)*	5.3 (0.4)	4.9 (0.4)	21.3 (1.8)	19.8 (2.1)
Shrub species richness	4.8 (0.2)	4.4 (0.2)	3.2 (0.1)	3.5 (0.1)*	0.2 (0.1)	0.8 (0.3)*
Conifer tree density (10 BAF prism)	3.3 (0.3)	3.7 (0.4)	0.8 (0.1)	1.9 (0.3)**	0.4 (0.2)	0.7 (0.3)
Conifer tree density (20 BAF prism)	6.6 (0.3)	7.8 (0.4)**	2.5 (0.2)	3.7 (0.6)	0.8 (0.2)	1.2 (0.5)
Conifer basal area (m^2/ha)	30.3 (1.2)	35.9 (1.7)**	11.5 (0.7)	17.0 (2.8)	3.8 (1.1)	5.4 (2.1)

[a] Significant *t*-tests of used vs. random plots are indicated by: * P < 0.05, ** P < 0.01, *** P < 0.001

Table 5.13. Habitat characteristics used by Mexican woodrats in two vegetation communities of the Sacramento Mountains, New Mexico. Only those variables that differed significantly between trap stations where woodrats were and were not captured are reported.

	Mesic Forest				Xeric Forest			
Variable	Random (n=35)		Used[a] (n=35)		Random (n=66)		Used[a] (n=66)	
Herbaceous cover (%)	39.1	(5.6)	24.3	(3.8)*	34.8	(3.2)	31.7	(2.8)
Shrub cover (%)	18.9	(3.8)	36.9	(5.4)**	13.5	(2.2)	23.0	(3.0)*
Shrub density (#/plot)	34.0	(6.6)	42.7	(5.5)	33.7	(4.3)	63.6	(14.0)*
Gray oak density (#/plot)	0.0		0.0		24.5	(4.0)	52.9	(13.8)*
Shrub, sapling, & seedling density	51.1	(11.2)	60.8	(8.2)	40.2	(4.6)	72.6	(14.3)*

[a] Significant *t*-tests of used vs. random plots are indicated by: * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

Table 5.14. Habitat characteristics used by long-tailed voles in two vegetation communities of the Sacramento Mountains, New Mexico. Only those variables that differed significantly between trap stations where long-tailed voles were and were not captured are reported.

Variable	Mesic Forest				Meadow			
	Random (n=156)		Used[a] (n=156)		Random (n=45)		Used[a] (n=45)	
Slope (degrees)	42.4	(1.1)	33.3	(1.1)***	16.7	(1.2)	20.1	(1.7)
Herbaceous cover (%)	25.1	(2.1)	56.4	(2.3)***	96.4	(1.2)	90.0	(2.8)*
Tree cover (%)	76.3	(2.2)	62.4	(2.8)***	16.7	(4.5)	20.9	(5.2
Bare ground (%)	71.0	(2.2)	37.7	(2.3)***	3.6	(1.2)	8.0	(2.7)
Litter depth (cm)	34.9	(1.6)	29.3	(1.7)*	[illegible]	6)	3.7	(1.4)
Grass-forb height (cm)	2.7	(0.3)	5.7	(0.6)***	20.6	[illegible]	21.3	(1.8)
Stump density (#/plot)	0.8	(0.1)	0.5	(0.1)*	0.0	(0.0)	0.0	(0.0)
Shrub density (#/plot)	36.3	(2.6)	59.4	(7.3)**	6.2	(2.6)	18.3	(5.0)*
Shrub, sapling, & seedling density	53.2	(3.9)	76.1	(8.5)*	12.0	(5.2)	30.0	(8.9)
Shrub species richness	4.9	(0.2)	4.7	(0.2)	0.4	(0.1)	1.0	(0.2)*
Conifer snag density (20 BAF prism)	0.8	(0.2)	0.4	(0.1)*	0.1	(0.0)	0.0	(0.0)
Conifer snag BA (m^3/ha)	3.9	(0.8)	1.9	(0.3)*	0.3	(0.2)	0.1	(0.1)

[a] Significant t tests of used vs. random plots are indicated by: * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

Table 5.15. Habitat characteristics used by Mexican voles in three vegetation communities of the Sacramento Mountains, New Mexico. Only those variables that differed significantly between trap stations where Mexican voles were and were not captured are reported.

	Mesic Forest				Xeric Forest				Meadow			
Variable	Random (n=155)		Used[a] (n=155)		Random (n=185)		Used[a] (n=185)		Random (n=40)		Used[a] (n=40)	
Slope (degree)	43.7	(2.6)	31.2	(3.4)**	31.9	(0.9)	33.0	(0.9)	22.2	(1.1)	13.2	(0.9)***
Herbaceous cover (%)	34.3	(6.3)	64.3	(6.2)**	34.9	(2.5)	43.2	(2.9)*	87.6	(2.4)	98.4	(0.9)***
Shrub cover (%)	33.3	(5.4)	15.7	(5.5)*	16.7	(2.4)	16.9	(2.1)	2.3	(1.2)	3.1	(1.0)
Tree cover (%)	76.7	(5.8)	37.6	(8.7)***	42.5	(3.7)	42.4	(3.7)	12.6	(3.4)	12.9	(3.3)
Bare ground (%)	56.7	(6.8)	31.0	(5.9)**	44.4	(3.2)	38.1	(2.8)	10.3	(2.1)	1.8	(1.0)***
Litter depth (cm)	31.0	(4.3)	20.1	(3.4)	17.6	(1.9)	20.3	(1.6)	2.3	(0.9)	9.5	(1.7)***
Grass-forb height (cm)	2.4	(0.6)	7.7	(1.7)**	5.1	(0.6)	7.2	(0.7)*	14.0	(1.5)	25.1	(1.4)***
Shrub density (#/plot)	40.0	(4.9)	22.6	(6.3)*	53.8	(11.6)	54.4	(10.6)	6.0	(2.5)	7.2	(4.3)
Shrub, sapling, & seedling density	58.5	(7.1)	31.9	(8.1)*	62.5	(11.7)	61.7	(10.9)	10.1	(4.6)	13.8	(8.6)
Shrub species richness	5.1	(0.6)	3.4	(0.7)*	3.4	(0.1)	3.3	(0.2)	0.5	(0.1)	0.3	(0.1)
Deciduous tree density (20 BAF prism)	1.3	(0.5)	0.1	(0.1)**	0.0	(0.0)	0.0	(0.0)	0.2	(0.1)	0.2	(0.2)
Conifer snag density (20 BAF prism)	0.5	(0.2)	0.2	(0.1)	0.1	(0.1)	0.4	(0.1)**	0.0	(0.0)	0.0	(0.0)
Deciduous tree BA (m^2/ha)	6.1	(2.1)	0.2	(0.2)**	0.1	(0.1)	0.0		0.7	(0.4)	1.0	(0.7)
Conifer snag BA (m^2/ha)	2.4	(1.0)	1.1	(0.5)	0.6	(0.2)	2.0	(0.5)**	0.2	(0.1)	0.00	

[a] Significant t-tests of used vs. random plots are indicated by: * P < 0.05, ** P < 0.01, *** P < 0.001

found on flatter areas with less rock but greater shrub cover, and greater density and basal area of live conifer trees (*t*-test, $P < 0.05$). Logistic regression identified slope, density of live conifer trees, litter depth, and number of shrub species as useful variables for distinguishing deer mouse habitat. Brush mice were found in areas having less tree cover, greater rock cover, shallower litter depth, greater densities of shrubs, gray oak, and conifer seedlings and saplings, but fewer conifer trees (Table 5.16). Logistic regression results indicated that brush mice used areas with shallower litter depth, greater shrub density, and fewer conifer trees. Mexican woodrats were captured in areas with greater shrub cover and density, and greater cover by gray oak (Table 5.13). Shrub cover was the only variable that discriminated capture from noncapture sites by logistic regression. Mexican voles were found at sites with greater herbaceous cover and height, and greater density and basal area of conifer snags (Table 5.15). Logistic regression identified two variables, density of conifer snags and height of herbaceous cover, as habitat discriminates for Mexican voles occupying xeric forests.

Meadows.—Deer mice, long-tailed voles, and Mexican voles were captured frequently enough to permit analyses. As in both forest types, deer mice occupying meadows were captured in areas with more exposed soil (Table 5.12). These mice also used areas with steeper slopes, shallower litter depth, and more shrub species (Table 5.12). Logistic regression indicated that only steeper slopes could be used to distinguish between capture and noncapture sites of deer mice. Long-tailed voles were captured at stations with less herbaceous cover, greater shrub density, and a greater number of shrub species (Table 5.14). Even though cover by herbaceous vegetation was less at capture stations, it still averaged 90.0% (SE = 2.8). Shrub density and herbaceous cover were the two variables that separated capture from noncapture sites using logistic regression. Mexican voles were found on flatter areas with greater herbaceous cover and height, greater litter depth, and less exposed ground (Table 5.15). Logistic regression identified slope, height of herbaceous vegetation, and litter depth as habitat variables associated with the presence of Mexican voles in meadows.

DISTURBANCE EFFECTS ON OWL PREY AND HABITAT

The distribution and abundance of the spotted owl's prey are influenced by both natural and anthropogenic factors. Though all factors to some degree have formative character, many are more accurately described as disturbance factors. Definitions of disturbance and the magnitude of associated effects vary according to ecological scale and conditions. Here, we briefly discuss fire, tree harvesting, and livestock grazing because these activities operate at spatial scales likely to influence spotted owls. Specifically, they may determine whether an owl occupies and reproduces in a given area. Important to this discussion is the element of human control over these disturbance activities.

We know little about direct cause-effect relationships of most natural and anthropogenic disturbance factors on owl prey populations. Correlative information allows us to infer some effects but most published research is from areas outside the range of the Mexican spotted owl. Their applicability to southwestern conditions is uncertain. Furthermore, effects of disturbance will vary by species, time, and space. Consequently, it is important to view disturbance at each of these scales. The issue becomes even more complicated when one considers the synergistic and cumulative effects of multiple disturbances. The latter scenario is more likely the norm than the exception.

Fire

Generalizing about the effects of fire on the owl's prey is impossible for a number of reasons including variations in fire characteristics and in prey habitat. Fire intensity, size, and behavior are influenced by numerous factors such as vegetation type, moisture, fuel loads, weather, season, and topography. Data presented in the previous sections illustrate how macrohabitat and microhabitat associations of the owl's prey vary both geographically within a species and among species.

Fire can effectively alter vegetation structure and composition thereby affecting small mam-

Table 5.16. Habitat characteristics used by brush mice in xeric forests of the Sacramento Mountains, New Mexico. Only those variables that differed significantly between trap stations where brush mice were and were not captured are reported.

	Xeric Forest			
Variable	**Random (n=184)**		**Used[a] (n=184)**	
Tree cover (%)	44.9	(2.5)	34.7	(2.3)**
Rock cover (%)	20.7	(1.7)	31.5	(1.7)***
Bare ground (%)	46.8	(2.0)	40.9	(1.9)*
Litter depth (cm)	21.2	(1.2)	11.8	(0.8)***
Stump density (#/plot)	0.3	(0.1)	0.1	(0.0)**
Shrub density (#/plot)	39.3	(3.6)	69.3	(7.4)***
Gray oak density (#/plot)	27.9	(3.4)	56.8	(7.2)***
Shrub, sapling, & seedling density	47.6	(4.0)	77.9	(7.6)***
Conifer tree density (20 BAF prism)	3.68	(0.38)	2.03	(0.13)***
Conifer tree BA (m^3/ha)	16.9	(1.7)	9.29	(0.61)***

[a] Significant *t*-tests of used vs. random plots are indicated by: * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

mal habitats. Population responses by small mammals to fire-induced changes in their habitat vary. For example, deer mouse populations might increase immediately following fire and then decrease through time (Peterson et al. 1985, Kaufman et al. 1988). Based on limited sampling efforts restricted to one location, Campbell et al. (1977) noted that populations of peromyscid mice decreased immediately following fire in an Arizona ponderosa pine forest that removed one-fourth (moderately burned) to two-thirds (severely burned) of the basal area; populations then returned to prefire numbers two years following the burn. Further, no differences were found in rodent populations between moderately and severely burned areas. They concluded that the effects of the fire that they studied were short-term, and the short-term positive numerical responses by mice were attributed to an increase in forage, particularly grasses and forbs.

However, we suspect that effects of more intense stand-replacing fires that dramatically alter forest structure and move the system to earlier seral stages would have longer-term effects on rodent populations. Likely, early successional species (such as the deer mouse) and those that require open habitats with a well developed herbaceous understory (such as microtine voles and pocket gophers) would benefit. In contrast, species that require a wooded or forested overstory would exhibit population declines. The net effect of such fires on spotted owls is unclear. A fire that removes the tree canopy would likely render the area unusable for foraging because of how spotted owls forage. But if the spatial extent of crown loss is limited, a mosaic is created that could provide a diversity of prey for the owl and actually be beneficial.

Clearly, research is required to determine the effects of fire on spotted owl prey. Because owl prey species evolved in ecosystems where fire was a natural process, we assume that these species survive and some even benefit from the occurrence of fire. Fire has been excluded from most southwestern ecosystems during the 20th century, resulting in systems where fire behavior may deviate substantially from natural conditions. Effects of fire on small mammals under present environmental conditions are unclear.

Timber Harvest and Fuelwood Removal

Numerous silvicultural methods are used to harvest timber in the Southwest. These include both even-aged (predominantly shelterwood systems) and uneven-aged (e.g., single tree, group selection systems) management. Further, these systems are applied differently according to site characteristics and management objectives. Given the various scenarios for silviculture, generalizing about their effects on prey populations is not possible.

Tree removal, whether to harvest sawlogs or fuelwood, will affect natural ecosystem processes in numerous obvious and obscure ways. Certainly, removal of mast-producing trees (e.g., pinyon pine, juniper, oak) reduces food availability for several of the owl's prey species. Also, removal of tree biomass from the site will interrupt both nutrient cycling and energy flow. The effects of altering these processes on owl prey populations is unknown, but the disturbance may likely benefit some species while negatively affecting others. Tree removal and accompanying site disturbance during and following removal, plus residual disturbance such as soil compaction, increased erosion, and creation of slash piles, will directly alter habitats of many prey species. Block and Ganey (unpublished data) found more deer mice in areas with slash than areas without slash. In the same general area, Goodwin and Hungerford (1979) noted that brush mice and Mexican woodrats used long windrows of slash following logging. Block and Ganey (unpublished data) sampled the same areas 18-20 years after the Goodwin and Hungerford study and captured few woodrats and brush mice. This suggests a temporary benefit of slash piles in that they may provide a short-term habitat component that is not used as the slash becomes compressed and decomposes.

As noted above, effects of tree removal on small mammals varies by prescription and site characteristics. The effects are somewhat scale dependent. Prescriptions for even-aged, shelterwood cuts or clearcuts effectively return large areas, the size of stands or greater, to earlier seral stages. Small mammal community structure is correlated to plant seral stage (Fox 1990, Kirkland 1990). Thus, following even-aged management, populations of some species will respond positively and others negatively. As time progresses and vegetation proceeds through succession, population dynamics of species will change in response to changing habitat conditions and community structure. Areas subjected to even-aged management may not provide appropriate foraging habitat for the spotted owl (see Ganey and Dick 1995). This means changes to small mammal populations within the harvested areas may not affect the owl prey base directly because those animals may not be available to the owl. However, the same small mammal populations may provide a source of individuals that disperse into adjacent owl foraging habitat.

Uneven-aged management would likely be used over large areas and does not create small stands, but rather it creates groups or clumps. Mosaics of habitat provide diverse plant communities and other conditions that, collectively, can support a rich diversity of fauna. Populations of different species may respond variably to aspects of the mosaic pattern, such as conditions within each patch type, patch size and shape, and interspersion and juxtaposition of these patches. Mosaic patterns resulting from timber management prescriptions such as single-tree or group selection cuts may in some ways mimic natural disturbance patterns and create canopy gaps. This does not imply that effects of silviculture are equivalent to those of natural disturbance, only that the resultant spatial patterns are somewhat similar.

Clearly, research is needed to determine cause-effect relationships of tree removal on spotted owl prey populations, the hunting ability of the owl, and the mosaic patterns which best conserve owl populations. Such research will entail experiments conducted at varying spatial and temporal scales to understand the true magnitude of the effects. Until these experiments are conducted, effects of tree removal on prey habitat and populations must be based on speculation and conjecture. Future management conducted within a scientific and experimental context may provide a means for establishing cause-effect relationships (see USDI 1995: Activity-Specific Research Section, Part III.E.).

Grazing

The effects of livestock and wildlife grazing on spotted owl prey populations and their habitats is also a complex issue. Impacts can vary according to grazing species; degree of use, including numbers of grazers, grazing intensity, grazing frequency, and timing of grazing; habitat type and structure; and plant or prey species composition. It is well documented and intuitive that repetitive, excessive grazing of plant communities by livestock can significantly alter plant species density, composition, vigor, regeneration, above or below ground phytomass, soil properties, nutrient flow, water quality, and ultimately lead to desertification when uncontrolled (Kauffman and Krueger 1984, Orodho et al. 1990, Vallentine 1990, Milchunas and Lauenroth 1993). These effects can have both direct and indirect adverse impacts on animal species that are dependent on plants for food and cover. However, moderate to light grazing can benefit some plant and animal species under certain conditions and in certain environments, maintain communities in certain seral stages, and increase primary productivity (Reynolds 1980, Hanley and Page 1982, Kauffman and Krueger 1984, McNaughton 1993). Further, direct influences of livestock on plant communities are not always reflected in small mammal communities (Grant et al. 1982). Thus, any generalizations presented here should not be construed as absolute; there are exceptions.

No studies document the direct and indirect effects of livestock and wildlife grazing on the Mexican spotted owl or its prey (see reviews by USDA Forest Service 1994, Utah Mexican Spotted Owl Technical Team 1994). We found only one study that specifically investigated the effects of livestock grazing on an upland forest owl, the tawny owl (Putnam 1986). However, the design and limited sampling effort of this study prevents extrapolation to the Mexican spotted owl. Interpretive extrapolations are further hampered because most livestock-effects studies on small mammals have been conducted in shrub-steppe, grassland, or riparian communities of arid or semi-arid regions (Kauffman and Krueger 1984, Milchunas and Lauenroth 1993). Except for the possible use of these areas for dispersing or wintering, such areas are not typically used by Mexican spotted owls.

Despite the dearth of specific information about spotted owls and grazing, there exists some knowledge regarding the effects of livestock grazing on small mammals frequently consumed by spotted owls and regarding mesic or montane plant communities inhabited by the owl's prey. Relevant studies include Hanley and Page (1982), Medin and Clary (1990), Schulz and Leininger (1991), and Szaro (1991), and are briefly summarized below.

In a 250,000 ha (619,250 ac) area of the Great Basin, Hanley and Page (1982) found that livestock grazing (primarily cattle with an average of 0.16 animal unit months April to October during each of four consecutive years) generally increased shrub composition and decreased perennial herbs and grasses (primarily tall bunchgrasses). However, these effects depended upon community type. Shrubs increased in grazed wet meadows and willow riparian communities, whereas tree-form willows decreased by 60%. Herbaceous layers were 30-50 cm (11.8-19.7 in) deep in ungrazed meadows compared to the "mowed" appearance of grazed meadows. Reduction of graminoids and forbs increased structural diversity in mesic habits by increasing shrubs but decreased structural diversity in shrub-dominated, xeric habitats. The authors postulated that the loss of perennial grasses and herbs caused lower numbers of desert woodrats, and long-tailed and mountain voles in grazed meadows by decreasing food sources and cover. The authors also reported a greater number of Great Basin pocket mice, deer mice, and least chipmunks in mesic habitats grazed by livestock compared to ungrazed, mesic habitats. However, these same three species decreased in xeric habitats grazed by livestock.

Schulz and Leininger (1991) examined the effects of cattle exclusion along one 5-km (3.1-mi) length of a riparian community in northcentral Colorado. During the summers of 1985 and 1986, plant and small mammal communities were sampled for comparison between adjacent grazed areas and three exclosures established in 1956 and 1959. Plant communities varied from grass-herb-sedge lowlands to ponderosa pine uplands. Observed differences included greater vascular vegetation cover, graminoid cover, and shrub cover in the exclosures. Litter accumulation in the exclosures was nearly twice that of grazed areas, and willow canopy cover was 8.5 times greater (Schulz 1990). Deer mice were significantly more abundant in grazed areas and western jumping mice were significantly more abundant in ungrazed exclosures. Seven species of small mammals were found in grazed and enclosed areas, although species composition in each area was slightly different. Deer mice, least chipmunks, masked shrews, dusky shrews, and western jumping mice were found in both areas. Long-tailed and mountain voles were not observed in grazed areas. Northern pocket gophers and golden-mantled ground squirrels were not found in exclosures.

Medin and Clary (1990) compared small mammal populations between a riparian habitat seasonally grazed by cattle to an adjacent 122-ha (302.2-ac) riparian exclosure which had been protected from livestock grazing for the previous 14 years. They found that mountain voles were four times more abundant within the ungrazed exclosure as compared to the grazed riparian habitat. In addition, vagrant shrews, water shrews, and northern pocket gophers were only trapped within the ungrazed habitat. Consequently, they noted that small mammal species richness and species diversity were higher within the ungrazed exclosure despite the fact that total population density of small mammals was a third higher in the grazed portion due to the high numbers of deer mice.

Szaro (1991) examined the effects of grazing along the Rio de las Vacas, a montane stream at 8,528 ft (2,600 m) elevation in the San Pedro Parks Wilderness Area, New Mexico. Terrestrial fauna within two 900 x 50 m (2,952 x 164 ft) livestock exclosures were sampled and compared to downstream private lands that were continuously grazed. Small mammals were sampled each month, June through September, in 1985 and 1986. He found greater amounts of herbaceous vegetation in the exclosures. Greater numbers of small mammal captures were observed in both exclosures in 1985 compared to grazed areas downstream. Small mammal captures were reduced and indistinguishable in 1986 but some cattle trespass had occurred into the control exclosures. Fewer species were captured in the grazed areas. Mountain voles and deer mice were found in both grazed and ungrazed situations, whereas least chipmunks and golden-mantled ground squirrels were found only in ungrazed areas.

Other studies have shown similar results: lack of a numerical decrease by deer mice to grazing (Reynolds 1980), and significant decrease in voles caused by grazing induced loss of cover in mesic habitats (Grant et al. 1982). If these general patterns can be applied to upland habitats of the Southwest, we would expect moderate to heavy grazing to decrease populations of voles and improve conditions for deer mice in meadow habitats. Such decreases could negatively influence spotted owls occupying areas in the Upper Gila Mountains, Basin and Range - East, and portions of other RUs where voles are common prey or used as alternative food sources when other prey species are diminished.

Increases in deer mouse abundance in meadows probably would not offset decreases in vole numbers because voles provide greater biomass per individual and per unit of area. Loss of perennial grass cover in xeric communities used by owls, specifically, ponderosa pine forest and pinyon-juniper woodlands, due to grazing may reduce deer mice and Mexican vole populations. The reduction of these prey species in xeric communities could be more critical than that in meadows if xeric habitats are necessary for winter foraging by the owls.

Finally, high intensity grazing in riparian communities during the fall and winter seasons where grass seedheads may be totally removed can cause significant short-term decreases in small mammal populations (Kaufman et al. 1983). Continued heavy grazing in upland or lowland riparian communities could therefore greatly reduce the potential for utilization by foraging, dispersing or wintering spotted owls.

CONCLUSIONS

Mexican spotted owls consume a variety of prey throughout their range but commonly eat small and medium-sized rodents. However, the owl's food habits vary according to geographic location. For example, spotted owls dwelling in canyons of the Colorado Plateau take more woodrats, and fewer voles and birds than do spotted owls from other areas. In contrast, spotted owls occupying mountain ranges with forest-meadow interfaces, such as the Basin and Range - East, Southern Rocky Mountains - Colorado, and Upper Gila Mountains RUs, take more microtine voles. The differences in diet likely reflect geographic variation in population densities and habitats of both the prey and the owl.

No strong rangewide relationships appeared in our analyses of the owl's diet and reproduction. The relationship was positive and nearly significant when comparing the prevalence of the three most common prey (peromyscid mice, woodrats, and voles) in the diet and owl reproduction, implying that multiple species influence the owl's fitness. However, this generalization may not apply to owls in the Sacramento Mountains where the owl's reproduction appears most influenced by deer mouse abundance. In addition, the predominance of woodrats, both in diet frequency and biomass throughout much of the owl's range, suggests that a single prey may influence the owl's fitness. Other studies have shown positive associations between larger prey (e.g. woodrats) in the diet of northern and California spotted owls and its reproductive success (Barrows 1987, Thrailkill and Bias 1989). The lack of more specific results should not imply that a simple relationship between diet and reproduction or other fitness measures does not exist. Rather, those relationships are more complex than are evident by the available information and analytical approaches used in producing this report. In most cases, total prey biomass is likely more influential on the owl's fitness than the abundance of any particular prey species. Other factors worth exploring would be lag effects such as the effects of winter diet on breeding potential, prey diversity, or synergistic effects of diet with factors like owl density, weather, and habitat.

Studies conducted in four vegetation communities demonstrate that abundance of the owl's food varies according to habitat and time. In the Sacramento Mountains, the greatest prey biomass is found in high-elevation meadows occurring along riparian corridors. Common prey species occupying these meadows are long-tailed voles, Mexican voles, and deer mice. However, abundance alone does not necessarily connote availability. Availability infers co-occurrence of owl and prey plus coincidental vulnerability to predation and ability to capture. Successful capture of meadow-dwelling rodents may be restricted to areas near forest edges coinciding with the presence of foraging perches. Rather, meadow habitats may play an indirect role by producing high densities of prey that become available to owls following dispersal into adjacent forests. Owls in the Sacramento Mountains consume a moderate-to-large proportion of voles during years of high vole density.

Summer prey biomass in mesic (mixed-conifer) forests can be greater than in xeric (ponderosa pine-pinyon-juniper-oak) forests of the Sacramento Mountains for two reasons. First, all five prey species common to this owl occur in mesic forest, whereas only four occur in xeric forests, where long-tailed voles are absent. This vole can provide an average mass of 32 g (1.1 oz) to an owl and it is the second most abundant species occurring in the mesic forests. Second, deer mice dwelling in mesic forest can attain great summer densities during certain years. This same pattern has not been observed in the seemingly more stable xeric forests. Prey composition and abundance in ponderosa pine-Gambel oak forests of northern Arizona are similar to the xeric forests of the Sacramento Mountains. In both areas, deer mice are ubiquitous and the Mexican woodrat and brush mouse are patchy in distribution and abundance. In contrast, Mexican voles are apparently less abundant in pine-oak forests of northern Arizona compared to xeric forests in the Sacramento Mountains. Whether low densities of voles in this forest type are natural or the result of past management activities is unknown. However, decreases in herbaceous biomass resulting from unnaturally dense forest conditions may explain low numbers of voles in these forests.

Arranging the four vegetation communities according to summer prey biomass indicates that meadows > mixed-conifer forest > ponderosa pine-pinyon-juniper-oak woodlands > ponderosa pine-Gambel oak forest. When considering other factors that influence the availability of prey, mixed-conifer forests likely provide the greatest amount of food during summer periods. Rearranging the same communities according to winter prey biomass indicates that meadows > ponderosa pine-pinyon-juniper-oak woodlands > ponderosa pine-Gambel oak forest > mixed-conifer forest. Accounting for the availability of prey, woodlands with a mixture of ponderosa pine, pinyon-juniper, and oaks provide more prey to owls during winter months than the other three communities.

Prey biomass is usually greater in all communities during summer periods when owls raise their young. However, temporal peaks of prey cycles are not correlated among vegetation communities. That is, when prey are abundant in mixed-conifer forest one year and low a subsequent year, an opposite pattern may occur in a different vegetation community. The asynchrony of abundance among prey species, vegetation communities, and time may provide a buffer against the effects of extreme oscillation in prey cycles. This implies the importance of maintaining a mixture of vegetation communities to ensure a diverse and abundant prey base within the owls foraging range.

An important concept exemplified by our analyses is that the habitat of each prey species is unique. This finding clearly indicates a need for providing a variety of conditions which are used by the different species of prey. For example, in the ponderosa pine-Gambel oak forests of northern Arizona, deer mouse abundance shows little variation according to forest structure and composition whereas Mexican woodrat and brush mouse abundance are strongly correlated to understory characteristics, specifically log volume and shrub cover. Further, Gambel oak density is greater within habitats of the woodrat and brush mouse than occurs randomly in the forest. These habitat components are rarely considered in planning forest management activities but should be to provide appropriate habitat conditions for these prey species. Obviously, conserving habitat for a diversity of prey may help buffer against population fluctuations of individual prey species and provide a less stochastic food resource for the owl.

The consequences of three common disturbances (fire, timber/fuelwood harvest, and grazing) on the owl's prey and habitat depends on many factors. Often ecological tradeoffs result, making exact predictions difficult. Some prey species may increase, while others decrease for a given disturbance. More detailed predictions about the influences of these disturbances must await more specific research. In general, management practices that lead to discernible reductions in total prey biomass or diversity over large areas will not promote owl recovery.

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APPENDIX 5a

Sources for estimates of prey mass used in calculating percent prey biomass in Mexican spotted owl diets.

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